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TASAR Flight Trial 2:

Assessment of Air Traffic Controller Acceptability of TASAR Requests

Husni Idris and Gabriele Enea
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June 2016

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Executive Summary

In support of the Flight Trial (FT-2) of NASA's prototype of the Traffic Aware Strategic Aircrew Requests (TASAR) concept, observations were conducted at the air traffic facilities to identify and assess the main factors that affect the acceptability of pilot requests by air traffic controllers. Two observers shadowed air traffic controllers at the Atlanta (ZTL) and Jacksonville (ZJX) air traffic control centers as the test flight pilot made pre-scripted requests to invoke acceptability issues and then they interviewed the observed and other controllers voluntarily. Fifty controllers were interviewed with experience ranging from one to thirty-five years. All interviewed controllers were enthusiastic about the technology and accounting for sector boundaries in pilot requests, particularly if pilots can be made aware of high workload situations. All interviewed controllers accept more than fifty percent of pilot requests; forty percent of them reject less than ten percent of requests. The most common reason for rejecting requests is conflicting with traffic followed by violating letters of agreement (LOAs) and negatively impacting neighboring sector workload, major arrival and departure flows and flow restrictions. Thirty-six requests were made during the test, eight of which were rejected due to: the aircraft already handed off to another sector, violating LOA, opposing traffic, intruding into an active special use airspace (SUA), intruding into another center, weather, and unfamiliarity with the requested waypoint. Nine requests were accepted with delay mostly because the controller needed to locate unfamiliar waypoints or to coordinate with other controllers. Based on the interviews, it is recommended that pilot requests maintain a minimum of three nautical miles from an active SUA at all times and avoid causing point outs to other controllers by maintaining at least 2.5 nautical miles from sector boundaries, particularly under high workload. Requests during handoff create coordination issues and can be avoided by making the request on average three to four minutes (depending on workload) before the handoff, which is automatically triggered when the aircraft is three nautical miles from the sector boundary. It is recommended that requests are made soon after a handoff to inform the controller of the pilot intension but to expect that the request will be handled after the aircraft crosses the boundary into the sector in control, particularly under high workload. Other insights include avoiding unfamiliar waypoints, violating LOAs, and opposing major arrival and departure flows.

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Acknowledgements

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1 Introduction

The Traffic Aware Strategic Aircrew Requests (TASAR) is an on-board automation concept intended to identify trajectory improvement opportunities clear of known traffic, weather, and airspace restrictions prior to the aircrew initiating a trajectory-change request to Air Traffic Control (ATC) [1-4]. The cockpit tool being developed to meet the objectives of the TASAR concept is called the Traffic Aware Planner (TAP). The technology is anticipated to increase ATC approval frequency and thereby provide benefits in areas such as flight efficiency, flight schedule compliance, passenger comfort, and pilot and controller workload [5]. NASA intends to use TASAR to help accelerate the adoption of Automatic Dependent Surveillance-Broadcast (ADS-B) equipage by the aircraft operator community. The TASAR Analysis and Development is being executed by the Langley Research Center's Crew Systems and Aviation Operations Branch (CSAOB) under the sponsorship of the Airspace Technology Demonstration (ATD) Project of the NASA Airspace Operations and Safety Program (AOSP). The contract team consists of Engility Corporation (hereafter called Engility) as the prime contractor with Advanced Aerospace Solutions, LLC (hereafter called AdvAero) as a sub-contractor.

The TASAR project aims to develop an onboard, traffic-aware, flight-optimization capability for near-term, low-cost implementation by airlines and other airspace users [4]. Previously, many activities were conducted to that end, including assessing benefits [5], safety/hazards [6], low-cost certification/approval [7], and human factors, culminating with Flight Trial 1 (FT-1) in November 2013 [8]. The objective of FT-1 was to conduct an initial validation of the TAP software application in flight with live avionics data feeds and allow for operational use by airline pilots in a live ATC environment. FT-1 confirmed that TAP is capable of performing its intended functions in this environment, taking a significant step forward in establishing its readiness for airline implementation [8, 9].

From the earliest days of the TASAR project, airlines have been consulted and engaged in order to assess their interest and to ensure TASAR was developed to meet their requirements and expectations. Through these outreach activities, airline interest in TASAR was immediately received, and NASA-airline partnership foundations were laid. NASA has established formal partnerships with Alaska Airlines and Virgin America for TASAR operational-use testing onboard revenue flights during 2016 and beyond.

The goal of Flight Trial 2 (FT-2) was to increase operational readiness of TASAR for these airline partnership activities. Picking up from the FT-1 initial assessment and demonstration of capability, FT-2 targeted a series of additional objectives that together will reduce TASAR adoption risk for the airlines. One of the objectives of FT-2 was to identify key factors that impact the air traffic controller acceptance of pilot requests to change their trajectories while in flight. Some trajectory requests are always unacceptable to controllers, such as ones that violate the separation requirement with another aircraft or are incompatible with an air traffic control (ATC) procedure. Other requests' acceptance depends on certain characteristics of the request and of the environment at the time of the request.

FT-2 focused on gaining insights on two types of controller acceptability factors:

1) the request interaction with airspace structure such as sector boundaries and special use airspace (SUA), and
2) the request maneuver complexity such as the number of waypoints and maneuvers.

FT-2 also investigated the interaction between these factors and environment factors such as workload and traffic patterns. These factors are characterized qualitatively and quantitatively. Outcomes of the analysis are recommendations for Traffic Aware Planner (TAP) advisory characteristics that address the identified acceptability factors.

2 Assessment Approach

Observation and elicitation of controller acceptability of pilot requests were performed during the flight trial. The observations were conducted at two en-route facilities, Atlanta Air Route Traffic Control Center (ZTL), from June 8 to June 16 2015, and Jacksonville Air Route Traffic Control Center (ZJX), from June 17 to June 20 2015, and included two components:

(1) Observation of scripted trajectory change requests that were designed to test hypothesized factors and were made by the test pilot. Observers on the ground monitored the pilot-controller communications during these requests and elicited acceptability factors from the controller through follow up interviews and questionnaires.

(2) Observation of pilot-controller communications in sectors without the test aircraft travelling through and eliciting acceptability factors through follow up interviews and questionnaires.

2.1 Acceptability Factors

A list of hypothesized acceptability factors was generated and confirmed during preparatory visits to ZJX and ZTL on October 15 and 16, 2014. Two sets of factors were considered: Controlled factors that were varied directly through scripted requests and environment factors that were varied indirectly. Eight controlled factors representing airspace structure interactions and maneuver complexity levels are described in Table 1 (six factors are depicted graphically).

The acceptability of the factors in Table 1 depends on environment factors, four of which are: the controller who handles the request, traffic density, traffic flow type (arrival, departure, or en route), and workload. It is important to attain a variation in these uncontrolled factors such that they do not mask the effects of the controlled factors. Therefore, these factors were varied indirectly by flying at different times such that requests were made from different controllers and during different traffic patterns and densities. The morning flights were alternated between 9 and 10 AM and the afternoon flights between 1 and 2 PM.

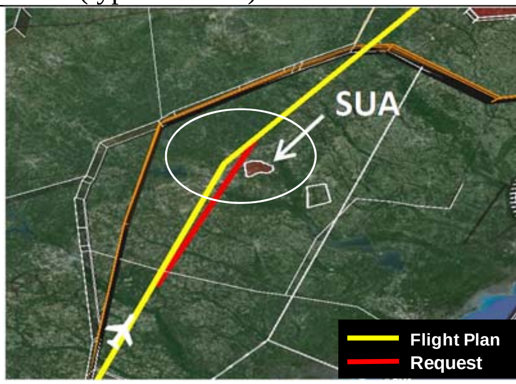
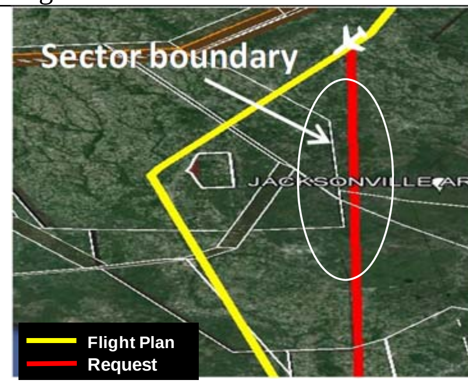
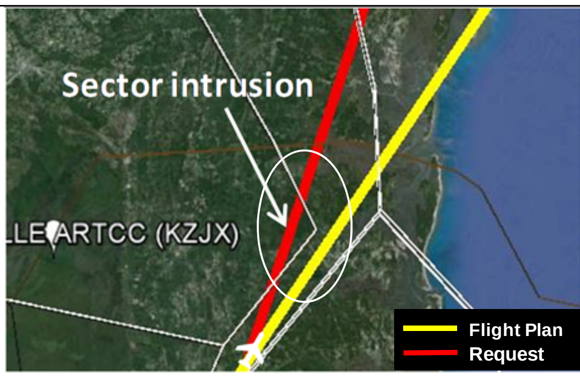
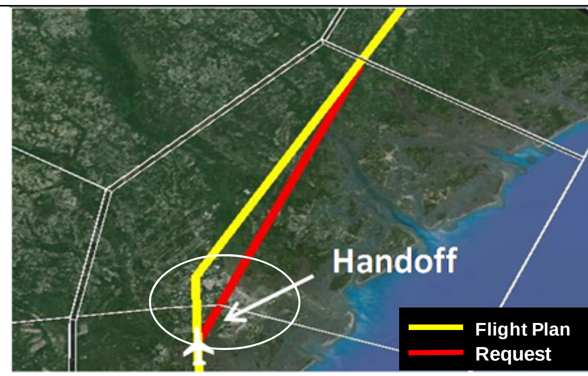
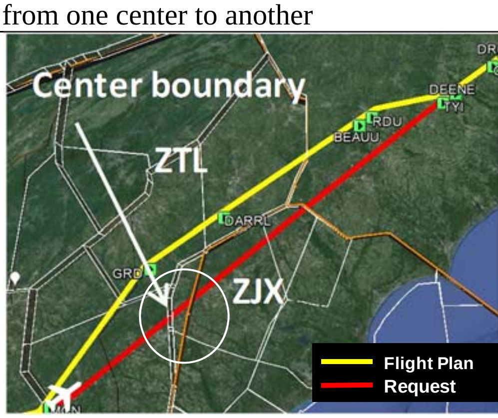
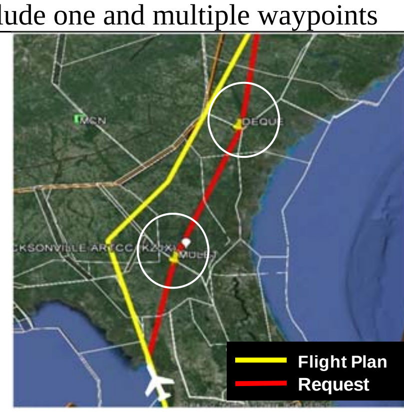
2.2 Scenarios / Experimental Matrix

Scenarios were designed for each request to invoke the factors in Table 1. Some scenarios invoked more than one factor, by design or by chance. In such cases, the request provided observations on multiple factors. The scenarios were scripted to cover, to the extent possible, all possible requests from every area of the sectors traversed by the test flight. This ensured the availability of scenarios to attempt even if the flight deviated from the nominal filed flight plan. Scenarios were also scripted with the assumption of no communication between the ground and airborne teams during the flight. Hence, the scenarios were collected in a booklet that was used by the ground observers and the TAP engineer onboard, who was in charge of planning and timing the requests. An example of the scenarios included in the booklet is presented in Figure 1. The order of the scenarios was determined by the ground observers before each flight and communicated to the TAP engineer onboard such that the two teams were coordinated, at least at the start of each flight.

In order to induce the geometry intended by the underlying factor, for example to fly close to a boundary between two sectors or to make a request closely before or after a handoff, a box was created to bound the location of the aircraft when the request was to be made. Example scenarios are shown in Figure 1 . Specific instructions were given along with the scenario to ensure that the request was made within the box as shown in the figure. For each scenario, instructions included:

- The requirements to identify if the scenario was applicable,
- The details on the request to instruct the test pilots,
- The geometric location along the nominal route to execute the scenario, and
- The frequency of the sector where to make the request.

Table 1 Controlled factors (Maps obtained from Google Earth).

<table>
<tr><td>1. SUA: Requests designed to fly close to three miles (typical buffer) from an SUA</td><td>2. Sector boundaries: Requests designed to fly along and across boundaries between sectors</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>3. Sector intrusion: Requests designed to cross in and out of sectors</td><td>4. Handoff: Requests made during or close to handoff status</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>5. Multiple centers: Requests made to cross from one center to another</td><td>6. Multiple waypoints: Request designed to include one and multiple waypoints</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>7. Multiple maneuvers: Request designed to include altitude and lateral maneuvers</td><td>8. Fix type: Request designed to use fixes in low altitude (E class) in addition to high altitude</td></tr>
</table>

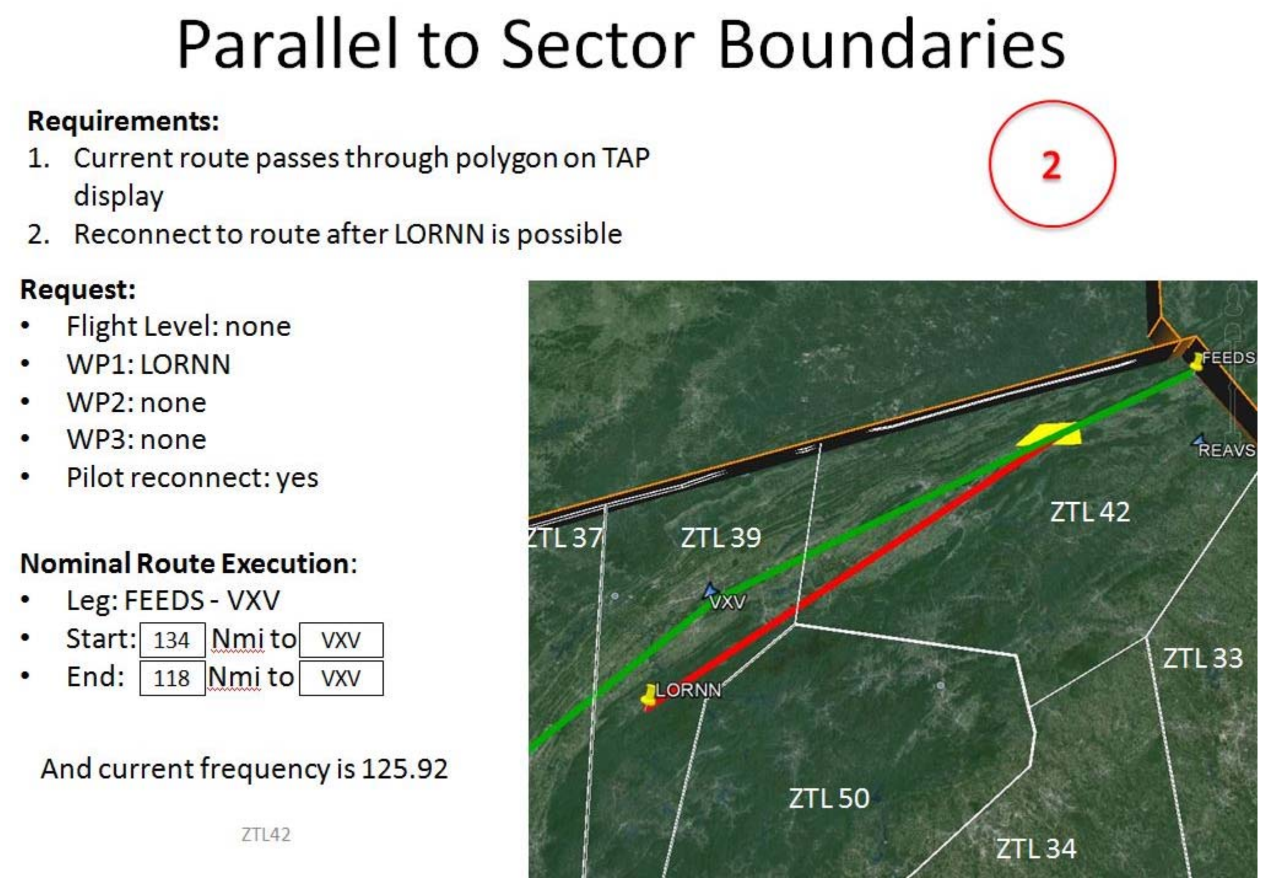


Figure 1 Example of scenario in the booklet (Map obtained from Google Earth).

In order to time the request correctly during the flight, the TAP engineer needed to know which sector the plane was in and its location relative to the targeted box. It was desired to also know the location with respect to sector boundaries to be able to make requests during handoff and fly along sector boundaries. This was achieved by matching the current ATC frequency with a frequency map provided by the FAA centers' personnel, and by using a tool that was provided to the TAP engineer to assist with locating the flight and timing the request. The tool consisted of a modified TAP version that provided the possibility to select the scenario number (the red number 2 in Figure 1) and overlap the relative polygon on the current route. A screenshot of the modified version of TAP is presented in Figure 2. The additional scroll-down menu to select the scenario number is visible in the bottom left of TAP. The scenario number was also displayed on the polygon.

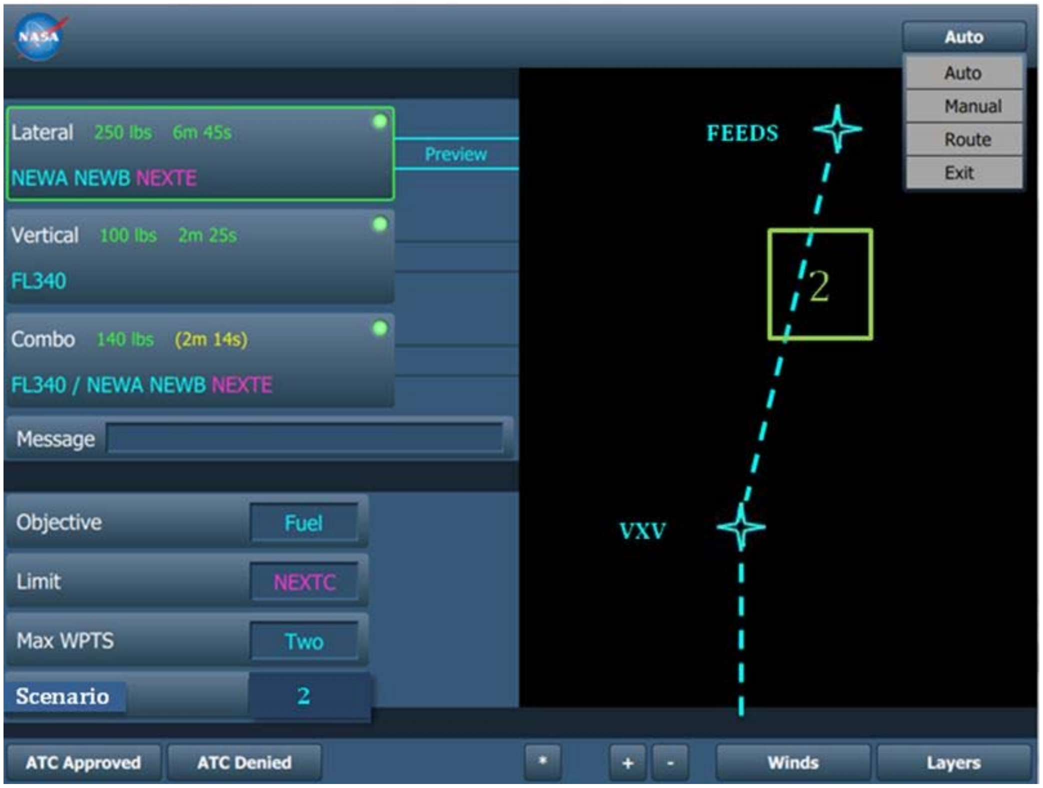


Figure 2 Screenshot of the TAP engineer version of TAP.

Off nominal conditions, such as weather, were not included in the pre-designed scenarios and test matrix because they may not materialize during the test. On one day of the observations significant weather impacted the test flight and scenarios were designed in real time as described below to interact with the weather.

Thirty-six total requests were initially assumed for data collection: A total of twelve flights (six flight pairs) were available for observation: Two flight pairs to Montgomery Regional Airport, Montgomery, AL (KMGM), two to Birmingham-Shuttlesworth International Airport, Birmingham, AL (KBHM), and two to Tampa International Airport, Tampa, FL (KTPA). A maximum of three requests per flight were assumed available for observation: two scripted and manually made and the third generated by TAP. An initial goal was set to invoke each of the eight controlled factors in Table 1 in four independent requests (repetitions) totaling thirty-two. The four remaining requests would be used as back up to repeat failed requests or add observations of off nominal events such as weather if they occur. During the test, some flights made fewer than three requests and some flights made up to four requests. Some factors that were concluded quickly as non-important were de-emphasized, such as the class of the fix used in a request (factor 8 in Table 1). Some requests were devoted to interact with weather which occurred on two days in ZTL. In ZJX, requests were devoted mostly to attempt to interact with active SUAs since ZTL did not have sufficient SUA activity and interacting with SUA in ZJX was challenging due to lack of activity during the test.

2.3 Observations Logistics

The logistics of the observation process were planned during the preparatory facility visits and were refined and finalized using telecons with the facility managers prior to the test. Two ground observers were positioned at ZTL or ZJX, where requests were planned. One or two facility personnel were dedicated to escort the observers at all times and facilitate the observations as needed. The FAA facility personnel were critical in making the observations successful in almost all of the activities performed as described below.

Preparation for the test flight started on the day prior to each flight. On that day, escorted by the dedicated facility personnel, the observers obtained briefings from the weather and traffic management units on the potential occurrence of weather or restriction activities that may disrupt the nominal flight plans of the next day. If disruptions were expected, the weather and traffic specialists were asked for suggestions on modifying the flight plans in order to achieve the experiment objectives. On that day, the dedicated personnel also helped in modifying the scripted scenarios based on their knowledge of procedures and common controller behavior. Some examples of critical suggestions are:

(1) Some of the scripted requests would not have been accepted because controllers do not accept deviations from certain routes used for delivery to the next center. Changes ranged from ensuring that the request is made prior to the no deviation point or more significant changes such as routing through a different sector.
(2) Some of the scripted scenarios were modified to avoid common controller short cuts that would have precluded the scripted requests.
(3) The personnel suggested some scenarios that invoke the underlying factors better than the ones pre-scripted based on their knowledge of common controller behavior and preferences.
(4) The personnel suggested that multiple requests from the same controller can be made without disturbing the controller, which increased the potential requests and interactions especially in large sectors.
(5) In ZJX, suggestions were elicited from the dedicated personnel and with the help of the special use airspace desk to script scenarios that increase the chance of interacting with active special use airspace.

Based on the recommendations from the facility personnel on the day prior to the test flight, the observers prepared new scenarios, modified the existing scenarios, changed the priorities of the scenarios, and communicated the changes to the airborne team. A telecon was held if needed to explain the changes. The observers also obtained the frequencies of all the sectors and included them in the scenarios to increase the awareness of the TAP engineer on board about the location of the aircraft while in flight.

The preparation for the test flight on the next day was the most important activity for the observers on the day prior to the test flight. If more time was available, the observers conducted additional observations of pilot-controller interactions by shadowing selected sectors and interviewing the observed controllers. The dedicated facility personnel were consulted for suggestions of sectors to observe. The selection was based on where high traffic and high user request activity were expected to manifest. The sectors were also selected mainly from areas different than the areas where the scripted routes and requests of the test flight were planned. This increased the pool of controllers that were observed and interviewed. The dedicated personnel helped in scheduling the interviews in coordination with the supervisors in charge of the observed sectors at the time.

On one of the days in ZTL, the weather activity was significant, and the observers decided that the flight plan should be modified to interact with the weather rather than conduct the pre-scripted scenarios. With the help of the dedicated personnel, new scenarios were scripted in real time and communicated to the flight crew prior to the flight. No off-nominal events impacted the flight on the other days.

The ground observers started each observation day when the test flight was operated by obtaining a weather briefing (by attending the facility briefing and talking to the weather specialist on site) to identify any weather events that may cause deviations from the nominal flight plans. They also met with the Traffic Management Unit to determine flow restrictions and expected traffic levels. Accordingly, they made adjustments to the nominal plans if needed, including new request priorities and scenario changes, for example, making a request in a different sector along a new route. In most cases, this consisted of changing the priority order of the scenarios in the booklet of scenarios which have been scripted for most possible deviations and used by the TAP engineer and ground observers. In some cases, such as when there were weather deviations in ZTL and when SUA activity was monitored in real time in ZJX, last minute route changes were communicated before the test flight takeoff. These changes were communicated in a

conference call that was held between the ground and airborne teams. If events during the flight rendered none of the scripted scenarios feasible, the TAP engineer was in charge of making requests based on knowledge of the objectives, the priorities, and the progress of the test matrix. If the TAP engineer's decisions did not match one of the scripted scenarios, the ground observers followed the flight as it transitioned through sectors and collected data accordingly.

One observer shadowed the controller of the sector where the flight was travelling and making requests. Once the next sector along the flight's route was determined with high certainty (but before handoff) the other observer started shadowing the controller of the next sector in anticipation of the flight's arrival. If the flight's route still changed due to a request or a controller clearance, the facility personnel assisting the observers alerted the second observer and changed his position to the correct next sector. The two observers then exchanged roles once the flight was handed off to the next sector, i.e., the second observer continued to observe the controller of the sector where the flight was traveling while the first observer started observing the next sector once known. With the help of the facility personnel assisting the observers, interviews with the observed controllers were scheduled (in consultation with the supervisors) after the flight exited from the sectors of interest. In some cases, the observers conducted interviews in parallel in separate rooms. The assisting personnel were asked to not be present during the interviews in order to avoid biasing the answers of the interviewees. For requests that transferred the flight to another center, the observations did not follow the flight to the next center.

2.4 METRICS / DATA COLLECTION

The main data source for identifying and characterizing controller acceptability of pilot requests was the interviews with the controllers. Fifty controllers were interviewed, 35 in ZTL and 15 in ZJX. Each controller was asked to read an informed consent form and sign it. All controllers who were observed accepted to conduct the interview and sign the consent form. The observers collected the data with the help of pre-designed data collection sheets. Four types of information were collected from each interviewed controller: (1) demographic information (2) general request acceptability statistics and factors (3) information regarding observed events, mostly events related to the scripted scenarios and (4) information regarding the hypothesized acceptability factors. Each of these types of information and their collection method/sheet is described below in this section. The analysis is given in the next section.

2.4.1 Demographic information

Figure 3 shows the age distribution of the fifty interviewed controllers for ZTL and ZJX. The age ranged between twenty-nine years and fifty-five years, with a mean of forty-two years.

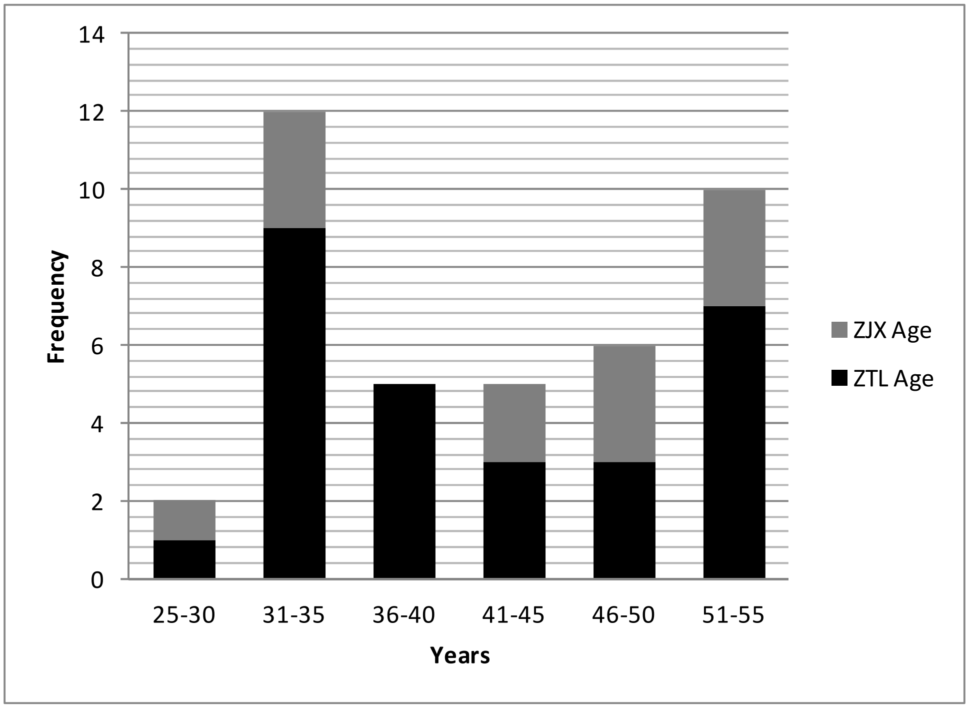


Figure 3 Controller age distribution.

Figure 4 shows the experience distribution of the fifty interviewed controllers for ZTL and ZJX. The experience ranged between two years and thirty-two years, with a mean of seventeen years.

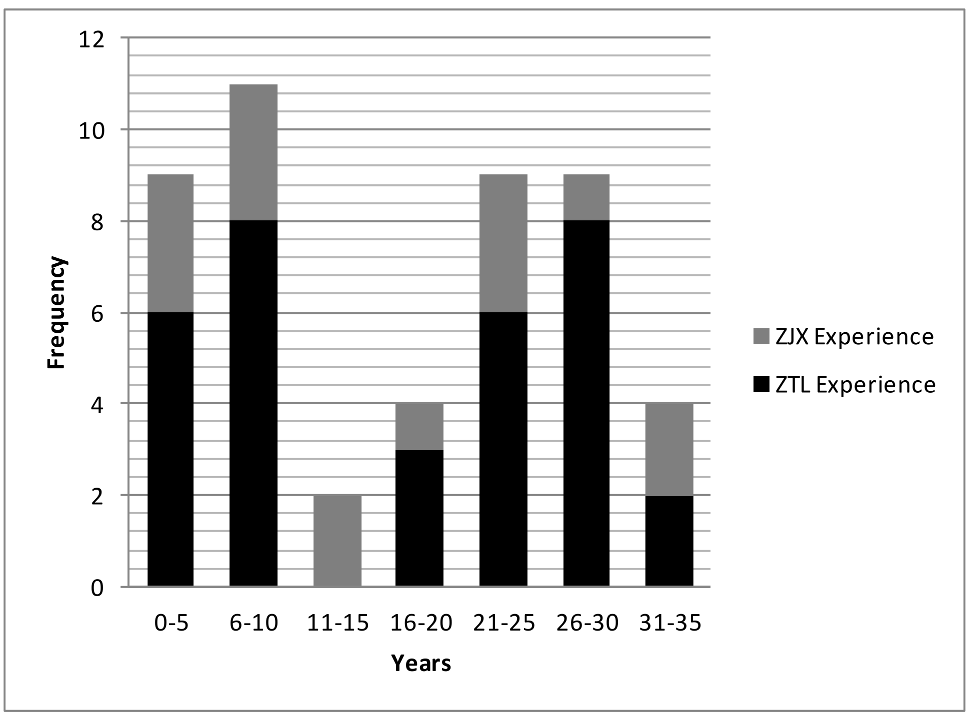


Figure 4 Controller experience distribution.

2.4.2 General statistics

Figure 5 shows an excerpt of the general questions that each controller was asked, along with sample responses from one controller. The analysis of the answers to each question is discussed in the next section.

Interview questions

1. What percentage of pilots makes requests for trajectory change? 20%

2. What is the most common type of trajectory change requested?
short cut

3. What is the next most common type of trajectory change requested?
altitude

4. What factors do you consider when evaluating a request?
(1) traffic
(2) workload
(3) do I have control. (handoff).
(4) proximity to airport destination.

5. What percentage of trajectory change requests do you reject? 20%

6. What reasons or factors make you reject trajectory change requests?
(1) traffic (2) workload [frequency congestion].
(3) Wx.

7. What is the most common reason for which you reject trajectory change request?
traffic.

Figure 5 General interview questions.

2.4.3 Event related information

When observing a sector, the observers used the observation collection sheet shown in Figure 6 to aid in collecting data about observed pilot request events. The same sheets were used for observing sectors when the test flight was flying through and for observing sectors without the test flight. The observers also complemented these sheets with notes jotted down on their personal notebooks. The information collected during the observation was fragmented and hence the sheet was completed to the extent possible during the interview with the controller following the observations. The information collected included in addition to the aircraft call sign and sector observed, the trajectory change request, the number of aircraft in the sector, the workload level as estimated by the controller, the type of traffic (arrival, departure or en route) at the time, the result of the request (accepted or rejected), the reason for rejection, and descriptions of the event including notes and pictorial depictions as needed.

Observed request data

Event ID: ______ Sector 37 Flight Callsign: ours Request time: 14:26

Trajectory change: route. CHNRD → CALCO-

Current number of aircraft in sector: ____________________

Workload level: __ High __ Moderate ✓ Low (based on: controller ✓ or observer __)

Traffic type: __ Arrivals ✓ Departures __ En route (Check all applicable if mixed traffic type)

Result: ✓ Accepted __ Rejected Additional notes: ____________________

If rejected, fill the following table:

Reasons for rejection	Unacceptable parameters/details	What makes it acceptable
SUA		
Sector boundary		
Sector incursion		
Center to center		
Handoff		
Maneuver complexity		
Number of waypoints		
Fix type		
traffic.		

Other observations / illustrations (draw situation if useful)

waited a bit 34 SGVA 767 ⊃34
for traff..
33 ↗ 34. clear altitude & then
put only Calca in Machine.
hadn't used CHNRD for while. pronounced
strange and lose on old arrival. not used
much anymore. then started VU7 so asked for it.

Figure 6 Pilot request event data collection sheet.

2.4.4 Factor characteristics

Each of the controlled factors was characterized by one or more parameters as shown in the excerpt data collection table in Figure 7. When an interview was granted, the observers asked focused questions to elicit quantitative values for the characteristic parameters to the extent possible. Assessment of each factor was obtained from each interviewed controller under three workload levels: high, moderate and low. These workload levels were subjective to each controller as each controller exhibits different levels of experience and skill. In order to recognize and document the subjective difference between the workload levels, each controller was asked to provide example situations of high, moderate and low workload levels based on their own experience, prior to collecting the data in Figure 7. An example workload data collection table is presented in Figure 8.

	High Workload			Moderate Workload			Low Workload		
	No	Margin	Yes	No	Margin	Yes	No	Margin	Yes
When a request is close to an active SUA, what distance from the active SUA is acceptable, marginally acceptable, or not acceptable?	required 3 miles	3				3			3
When a request parallels or hugs the boundary between two sectors, what distance from the boundary is acceptable, marginally acceptable or not acceptable?	have to have 2.5		3			0			0
When a request clips a sector, what duration in the sector is acceptable, marginally acceptable or not acceptable?	no issue				no issue			→	
When a request is made near the handoff to another sector, what time before the handoff is acceptable, marginally acceptable, or not acceptable?			5min			2			2
When a request is made near the handoff from another sector, what time after the handoff is acceptable, marginally acceptable, or not acceptable?			0			0			0
When a request is made near the handoff to another center, what time before the handoff is acceptable, marginally acceptable, or not acceptable?		some							
When a request includes additional waypoints, what number of additional waypoints is acceptable, marginally acceptable, or not acceptable?		≤5			>5		whole route.		
When a request includes lateral, vertical, or combination of the two maneuvers, which are acceptable, marginally acceptable or not acceptable?	altitude at most.								
When a request includes a variety of fix types, which fix type A or E are acceptable, marginally acceptable, or not acceptable?	spelling issue only if in system.								
Other (State question)									

Figure 7 Factor characteristics data collection sheet.

8. What constitutes high, moderate, and low workload? Give an example of each situation

High workload	Moderate workload	Low workload
wx + ≥ 5 o/c.	15 o/c w/o a light wx	< 10 no wx.

Figure 8 Workload assessment example.

3 Analysis and Results

The analysis of the collected data is presented in this section with results in terms of insights on controller acceptability of pilot requests and recommendations for design of the TAP trajectory change request advisories. First some statistics that resulted from the generic questions are presented followed by statistics related to the characteristics parameters of the specific hypothesized acceptability factors.

3.1 General Statistics

Controllers were asked what percentage of pilots makes trajectory change requests; Figure 9 shows the frequency of the controller answers. The percentage is shown on the x-axis as bins of 10 percent. Some of the controllers provided percentages of pilots that make requests under bad weather and turbulence (bad rides) conditions in addition to under nominal conditions. Therefore, the answers that laid within each bin were divided into the answers under nominal, bad weather and turbulence. The percentages under nominal conditions are also divided between the ZTL and ZJX controllers to see if there are differences depending on the facility.

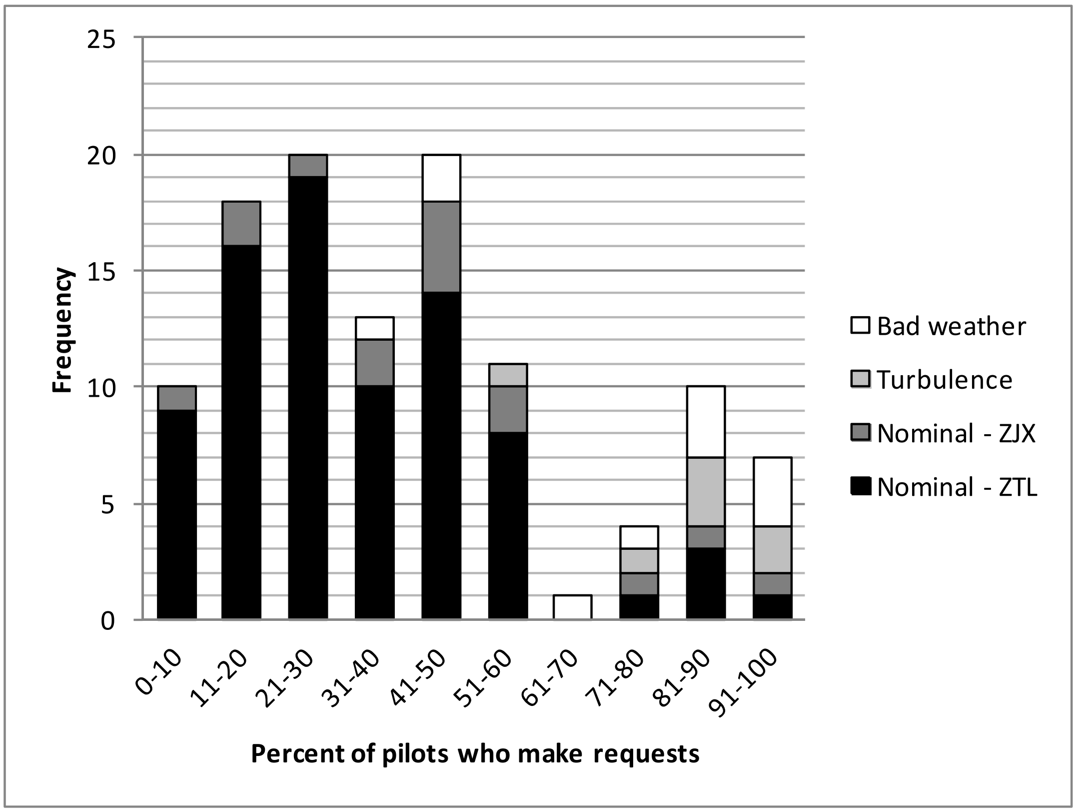


Figure 9 Percentage of pilots making trajectory change requests.

Under nominal conditions, most ZTL controllers answered that thirty percent of pilots make requests (with a mean of 33 and standard deviation of 20) while most ZJX controllers answered that about fifty percent of the pilots make requests (with a mean of 49 and standard deviation of 25). Most of the controllers answered that ninety to hundred percent of the pilots make requests under bad weather and bad ride conditions. Some indicated that the bad ride conditions are often worse than thunderstorms in this respect as all pilots ask for better rides. Note that the number of answers in Figure 9 is larger than the number of controllers interviewed because some controllers provided answers under multiple conditions. As a side note, some controllers

commented that some airlines make more requests than others, indicating subjectively that hundred percent of the pilots of certain airlines make requests for short cuts or better altitudes.

Controllers were asked what the most and next most common types of trajectory change requests pilots make and Figure 10 shows the frequency of the answers. The short cut request is the most common and was mentioned by thirty-nine controllers as the most common request and by eight controllers as the next most common request. It is followed by altitude change request, which was listed as the most common request by nine controllers but as the next most common by twenty-nine controllers. Finally weather deviation requests were mentioned by one controller as the most common type and by twelve controllers as the next most common request. The dominance of these factors was the same in ZTL and ZJX, and hence, they are not differentiated by facility in Figure 10.

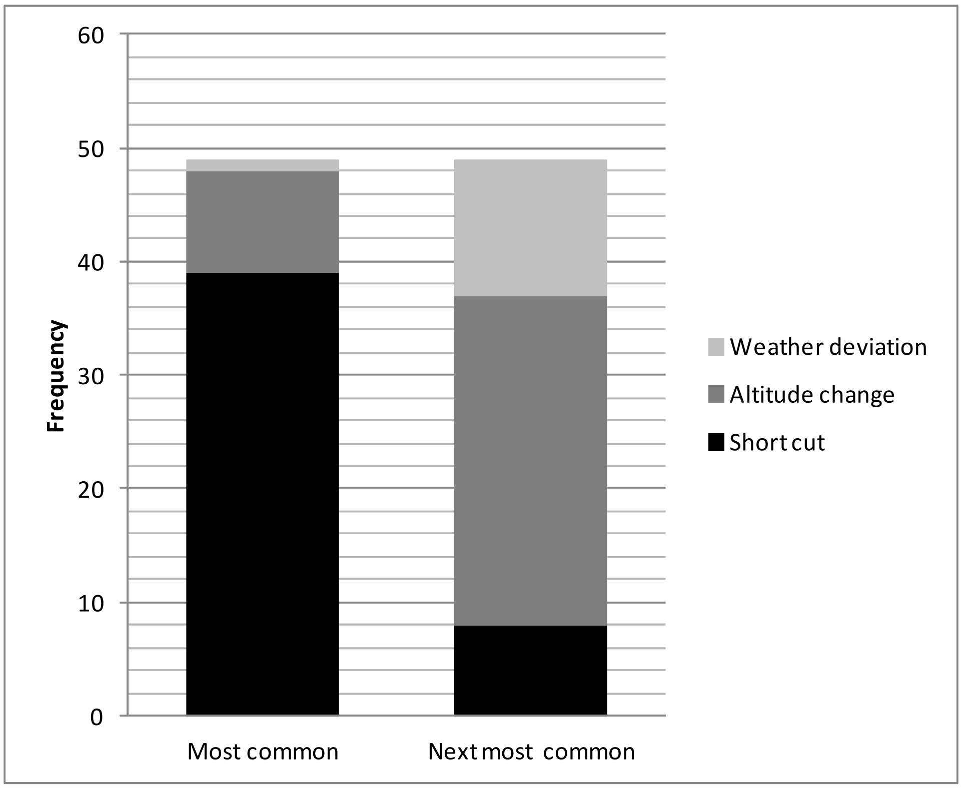


Figure 10 Most common pilot trajectory change requests.

Figure 11 shows the frequency of the main factors that the controllers mentioned they consider when evaluating a pilot request for trajectory change. The factors are ordered on the horizontal axis by their overall frequency. Each factor's frequency is divided into its occurrences as first, second, third or fourth factor. While the controllers were not asked to rank the factors that they mentioned by importance, the order in which they mentioned the factors may carry such implication. It should also be noted that the controllers were not forced to provide four factors; many of them provided a smaller number of factors. Therefore, the total occurrence of factors as first is higher than the occurrence of factors as second, which is higher than their occurrence as third, which is finally higher than as fourth.

Traffic confliction was mentioned by far most frequently by controllers as the first factor they consider when evaluating pilot requests for trajectory change. It should be noted that the questions were subjective and no effort was made to define each term that was mentioned by a controller objectively across controllers due to the time constraint of the interview. Therefore, traffic confliction may represent to one controller a larger set of events than to another controller. As an example, traffic flow appeared as a factor with low

frequency; however, for some controllers it may have been assumed under traffic confliction. Arrivals/departures was the third most mentioned factor; it was often associated with specific streams such as those of the major airports Atlanta and Charlotte. Flying opposite to a busy arrival flow may have been mentioned as arrivals/departures confliction by one controller but assumed as part of traffic confliction by another controller. The same can be said about factors such as workload which may encompass many other factors and about flow restrictions which often included LOA type constraints in addition to traffic management initiatives and in-trail spacing. Therefore, the ranking should be taken as a subjective one, and the insights mainly are in the list of factors rather than the frequency of each factor.

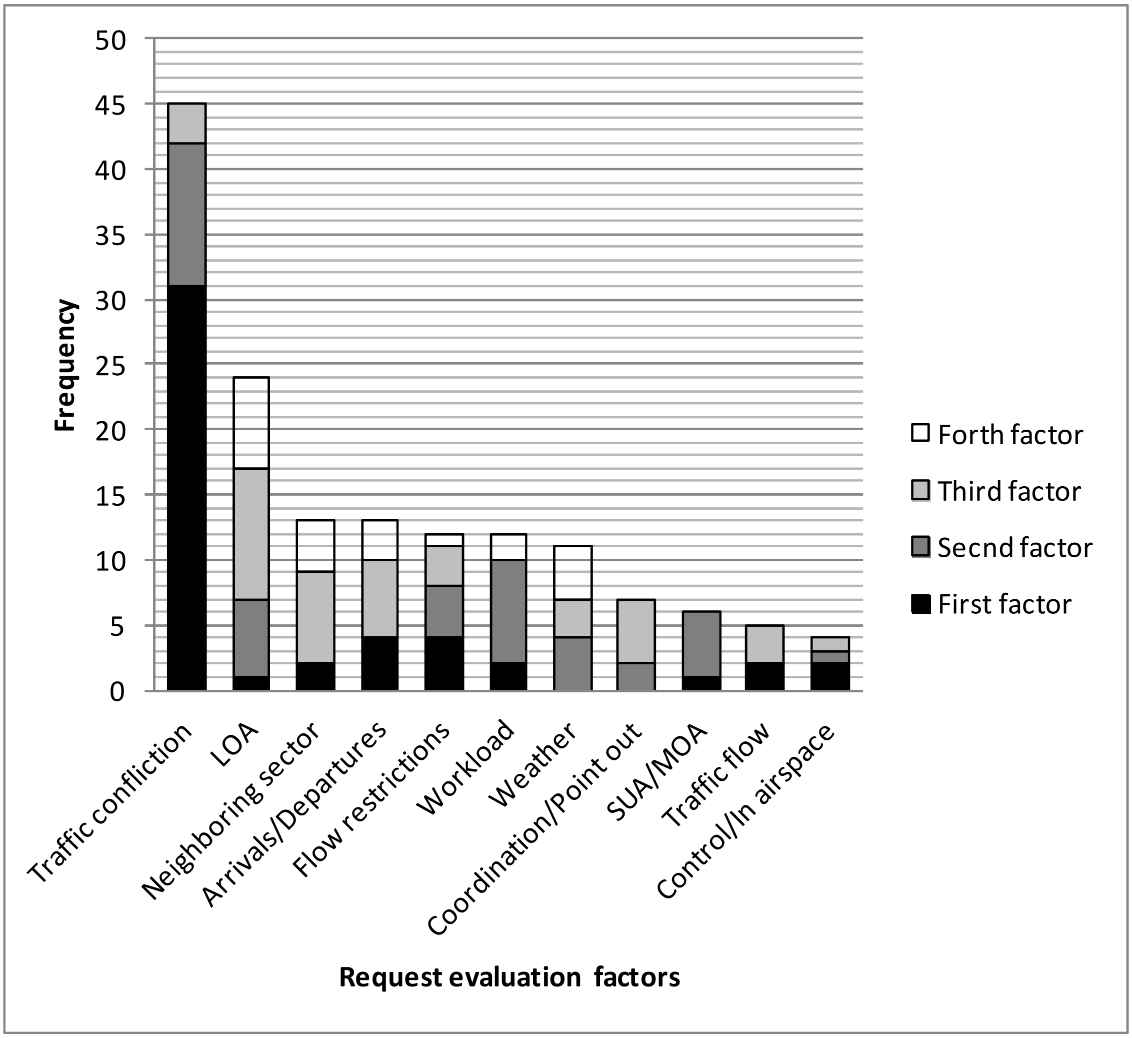


Figure 11 Factors for controller evaluation of pilot requests.

Figure 12 shows a frequency plot of the rate at which controllers reject pilot requests for trajectory change. Most controllers mentioned that they reject less than ten percent of the pilot requests and all answers were below fifty percent. Both ZTL and ZJX controllers attempt to be accommodating to pilots and grant the requests unless there is a very good reason not to. For example, some of the requests cannot be granted if they violate ATC procedures such as LOAs. General agreements and expectations between facilities and between adjacent controllers are also important even if they are not written in ATC procedures. For example, most controllers mentioned that they would not accept a request that causes high workload and coordination activities for other controllers. In ZJX, few controllers mentioned that they would go as far as

asking a Military Operations Area (MOA) if they can accept a point out to allow aircraft to travel through or close to its boundary.

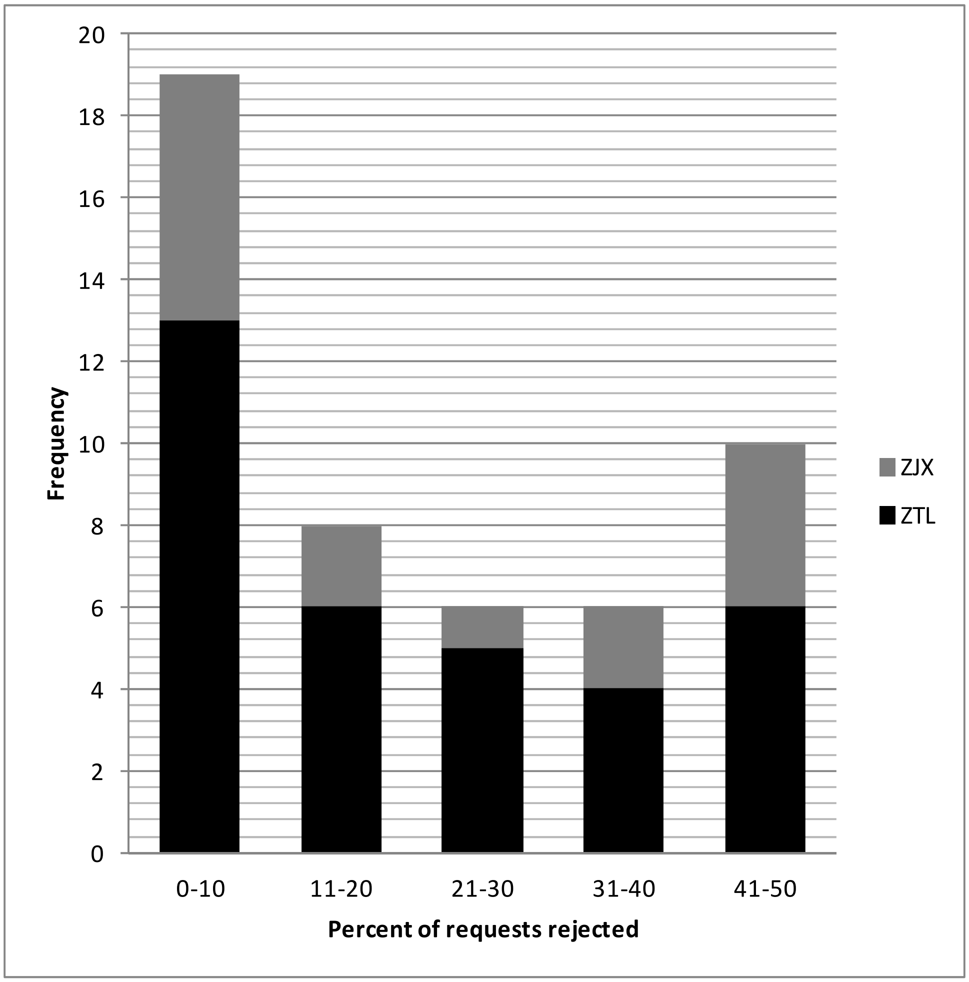


Figure 12 Percentage of pilot requests that are rejected by controllers.

Controllers were also asked about the main reasons for rejecting a request. These answers were mostly identical to the factors that were listed for evaluating a request with traffic confliction as the dominant reason for rejecting a request. Hence, they are not analyzed separately here.

3.2 Factor Characteristics

The following subsections describe statistics and insights from the data collected about each of the hypothesized controller acceptability factors.

3.2.1 Request to fly close to active SUA

Controllers were asked how close to an active SUA a trajectory change request can be to be acceptable. A summary of the statistics resulting from the interviews for the acceptable distance from an active SUA is presented in Table 2. Most controllers replied with a range of values for each workload level, therefore the data are presented with an upper and lower limit values as shown in Table 2. The number of controllers who answered the question is given in the last row of the table. While most controllers provided answers for the low and high workload levels, some controllers did not provide an answer for the moderate workload level. It must be noted that the required separation minimum from an active SUA is three Nautical Miles.

Table 2 Statistics of acceptable distance from active SUA [Nmi].

	Low Workload		Medium Workload		High Workload	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Minimum	0.00	0.00	2.00	2.00	0.00	0.00
25th quartile	3.00	3.00	3.00	3.00	3.00	3.00
Median	3.00	3.00	3.00	4.00	5.00	5.00
Mean	3.22	3.45	3.76	3.88	4.29	4.50
Mode	3	3	3	5	5	5
75th quartile	3.75	5.00	5.00	5.00	5.00	5.00
Maximum	5.00	5.00	5.00	5.00	10.00	10.00
Standard deviation	1.16	1.24	1.03	1.04	1.67	1.93
Number of controllers	46	46	37	37	47	47

The acceptable distance from an active SUA ranged between a minimum of zero under low workload and a maximum of 10 nautical miles under high workload. It is evident from the mode statistics in Table 2 that the majority of controllers answered that they would accept requests that are at the legal minimum distance of 3 nautical miles under low workload but they require five nautical miles under high workload. The increasing trend of the mean acceptable distance from an active SUA with the workload level can be seen in Figure 13. It increases from a range of 3.22-3.45 at low workload to a range of 4.3-4.5 nautical miles at high workload. The standard deviation of the data (presented as error bars) also increased with the workload level.

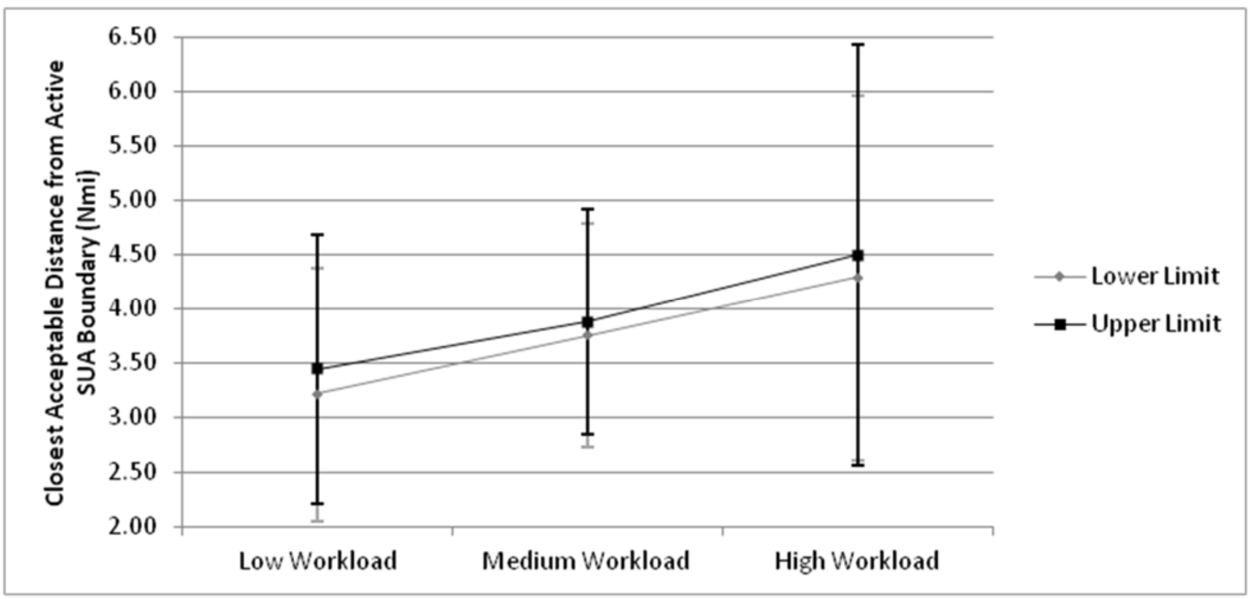


Figure 13 Acceptable mean distance from active SUA under different workload.

The dependence of the acceptable distance on workload is also supported by the distribution of the data shown in Figure 14. The distribution shows the frequency of the controller answers, taken as the mean between the lower and upper limit values, in bins of two nautical miles and categorized by the workload level. Clearly larger acceptable distances are mentioned more frequently under high workload.

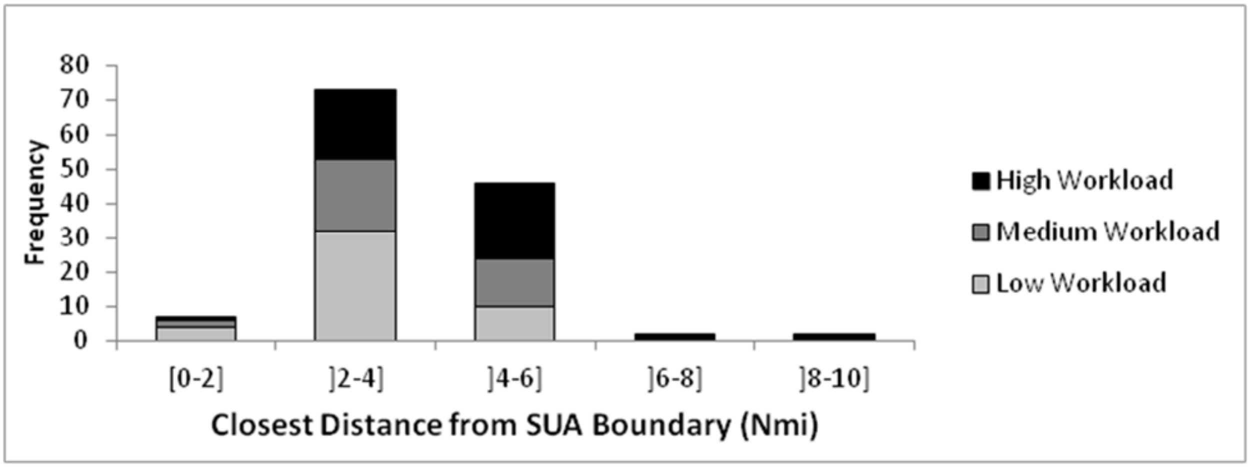


Figure 14 Distribution of closest acceptable distance from active SUA.

Based on the analysis of the controller answers, it is recommended that trajectory change requests maintain the minimum separation of three nautical miles at all times. It is also recommended that if the pilot is aware of the controller workload level, that the trajectory change request maintains about five nautical miles distance from the active SUA during high workload.

It should also be noted that some experienced controllers in ZJX commented that they would negotiate with the military authority to allow a trajectory change request to penetrate into an active SUA if the activity in the SUA was low and if there was an operational need such as in the presence of weather. Therefore, closer distances to an active SUA can be entertained if needed.

3.2.2 Request to fly along sector boundaries

Controllers were asked how close to the boundary between two sectors can a requested trajectory travel in order to be acceptable. The main issue with flying close to the boundary between sectors is the necessity of point out. If an aircraft flies closer than 2.5 nautical miles from the sector boundaries, the controller in charge of the aircraft has to call the controller of the adjacent sector to have him/her monitor the aircraft as well. This procedure is known as point out and causes an increase in workload. Although it is very common for controllers to point aircraft out, under high workload they can decide to either reject or delay a request that needs a point out in order to create enough separation from the sector boundaries and avoid the coordination necessary for the point out.

A summary of the statistics resulting from the interviews for the acceptable distance to maintain from sector boundaries is presented in Table 3. The statistics are shown for an upper and a lower limit under each workload level. However, the upper and lower limits are very close since most controllers provided one value rather than a range for this factor. The number of controllers who answered the question is given in the last row of Table 3. While most controllers provided answers for the low and high workload levels, some controllers did not provide an answer for the moderate workload level.

The answers ranged between a minimum of zero nautical miles at low workload and a distance of six nautical miles at high workload. In the interview data, a distance of zero represented that the controller would accept a request that creates the necessity of a point out. From the data in Table 3, it is evident from the mode statistic, which is equal to zero under all workload levels, that most controllers, in all workload situations, would accept a request that has the aircraft flying parallel to the boundaries of two sectors. In high workload situations, the mean response is below two miles (1.9) and the median goes up to 2.5 miles, indicating that the controllers would increasingly reject requests that create point out situations.

Table 3 Statistics of acceptable distance to fly parallel to sector boundaries [Nmi].

	Low Workload		Medium Workload		High Workload	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
25th quartile	0.00	0.00	0.00	0.00	0.00	0.00
Median	0.00	0.00	0.00	0.00	2.50	2.50
Mean	0.64	0.64	1.24	1.29	1.90	1.92
Mode	0	0	0	0	0	0
75th quartile	0.00	0.00	2.50	2.50	3.00	3.00
Maximum	4.00	4.00	4.00	5.00	6.00	6.00
Standard deviation	1.20	1.20	1.54	1.67	1.65	1.68
Number of controllers	43	43	34	34	44	44

An upward trend of the mean distance required by controllers with workload is visible in Figure 15 where the mean acceptable distance increases from half nautical mile at low workload to about two nautical miles at high workload. Most controllers did not distinguish between lower and upper bounds for each workload level and provided only one value making the range between the lower and upper limits almost invisible. The difference in standard deviations is also very small indicated by the almost overlapping error bars. A similar trend is observed in the distribution of the data shown in Figure 16 where higher acceptable distances from sector boundaries (of four to six miles) are mentioned more frequently under high workload.

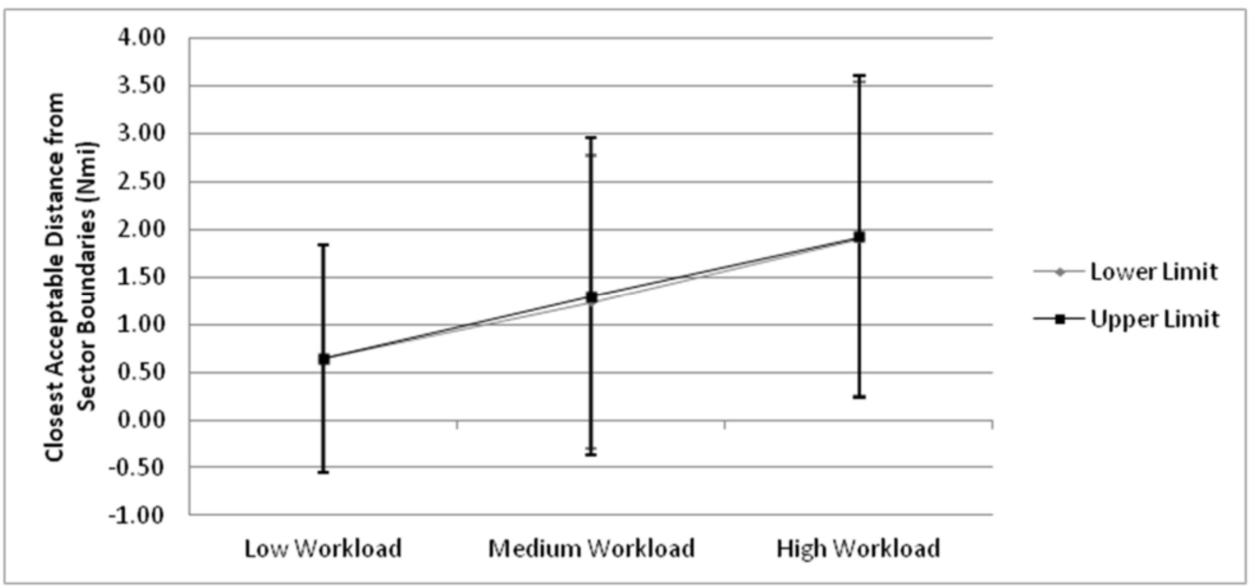


Figure 15 Acceptable mean distance to fly parallel to sector boundaries under different workload.

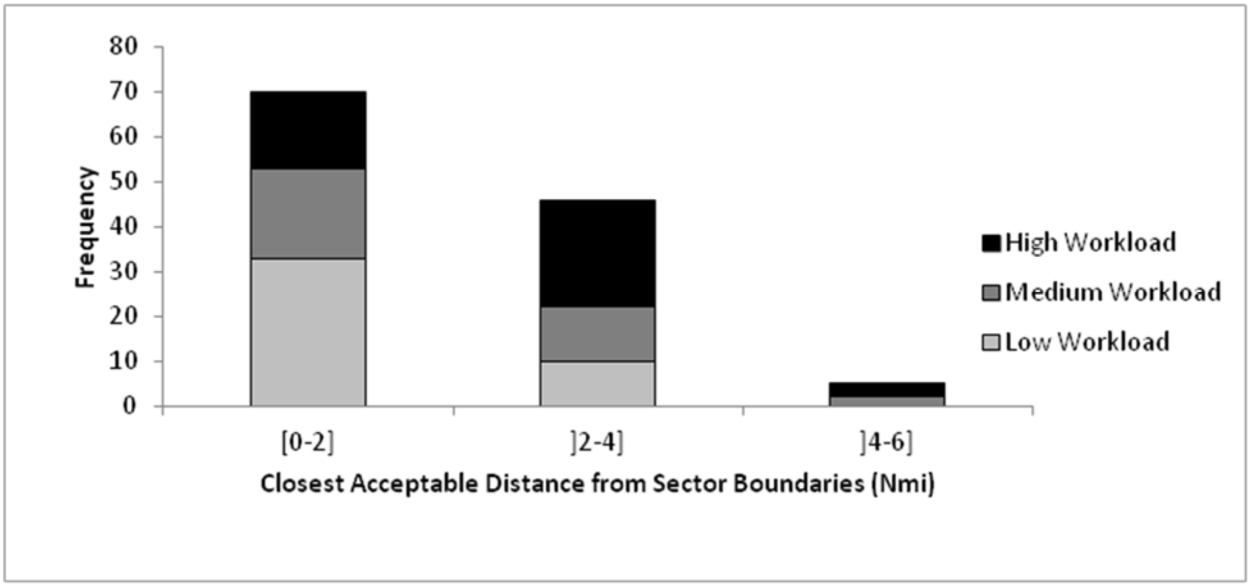


Figure 16 Distribution of closest acceptable distance from sector boundaries.

Based on the analysis of the controllers' answers, it is recommended that a trajectory change request avoids a point out situation under high workload situations. This can be achieved by ensuring the required 2.5 nautical miles from the boundary between two sectors.

3.2.3 Request causing sector intrusion

Controllers were asked if they would accept requests that intrude briefly into a sector (clip a sector) and, if not, how far they would want a request to be to avoid clipping. The issue in clipping a sector is causing a point out to the clipped sector similarly to the previous factor (flying along sector boundaries). Controllers are required to point out an aircraft that clips a sector, potentially adding workload to the controllers of the sector that is being clipped and to their own because of the coordination required. To avoid the point out, as explained for the previous factor, controllers would have to keep the aircraft more than 2.5 Nautical Miles away from the adjacent sector's boundaries.

A summary of the statistics resulting from the interviews for the sector clipping factor is presented in Table 4. Most controllers replied with a range of values for each workload level, therefore the data are presented with an upper and lower level value as shown in Table 4. However, the upper and lower limits are very close since most controllers provided one value rather than a range for this factor. The number of controllers who answered the question is given in the last row of Table 4. While most controllers provided answers for the low workload levels, some controllers did not provide an answer for the moderate and high workload levels.

The acceptable distance ranged between a minimum of zero under low workload and a maximum of nine nautical miles under high workload. Similarly to the previous factor, the majority of controllers answered that they would accept requests that clip sector boundaries. This is reflected in the statistics presented in Table 4, where the mode of the answers, for all workload levels, is in fact zero which indicates that most controllers would not require any distance from clipping a sector. The median is also zero for all workload levels. In high workload situations, the mean response is below two miles (1.6), indicating that the controllers would increasingly reject requests that create point out situations.

Table 4 Statistics of closest acceptable distance from sector clipping [Nmi].

	Low Workload		Medium Workload		High Workload	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
25^{th} quartile	0.00	0.00	0.00	0.00	0.00	0.00
Median	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.14	0.14	0.56	0.59	1.54	1.60
Mode	0	0	0	0	0	0
75^{th} quartile	0.00	0.00	0.00	0.00	3.00	3.00
Maximum	3.00	3.00	4.00	5.00	8.00	9.00
Standard deviation	0.61	0.61	1.21	1.31	1.98	2.12
Number of controllers	40	40	32	32	34	34

An upward trend of the mean distance required by controllers and its standard deviation (presented as error bars) with workload is visible in Figure 17 where the mean acceptable distance increases from almost zero at low workload to about 1.5 nautical miles at high workload. Most controllers did not distinguish between lower and upper bounds for each workload level and provided only one value making the range between the lower and upper limits almost invisible. A similar trend is observed in the distribution of the data shown in Figure 18 where higher acceptable distances from sector clipping are mentioned more frequently under high workload.

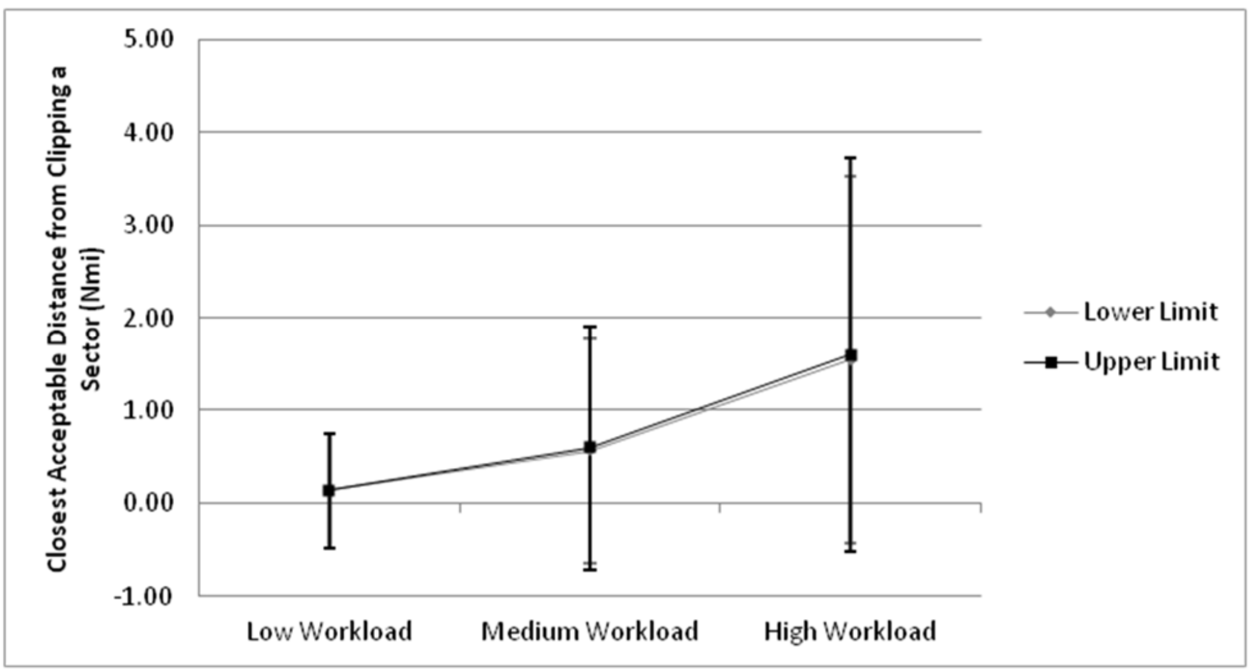


Figure 17 Mean acceptable distance from sector clipping under different workload.

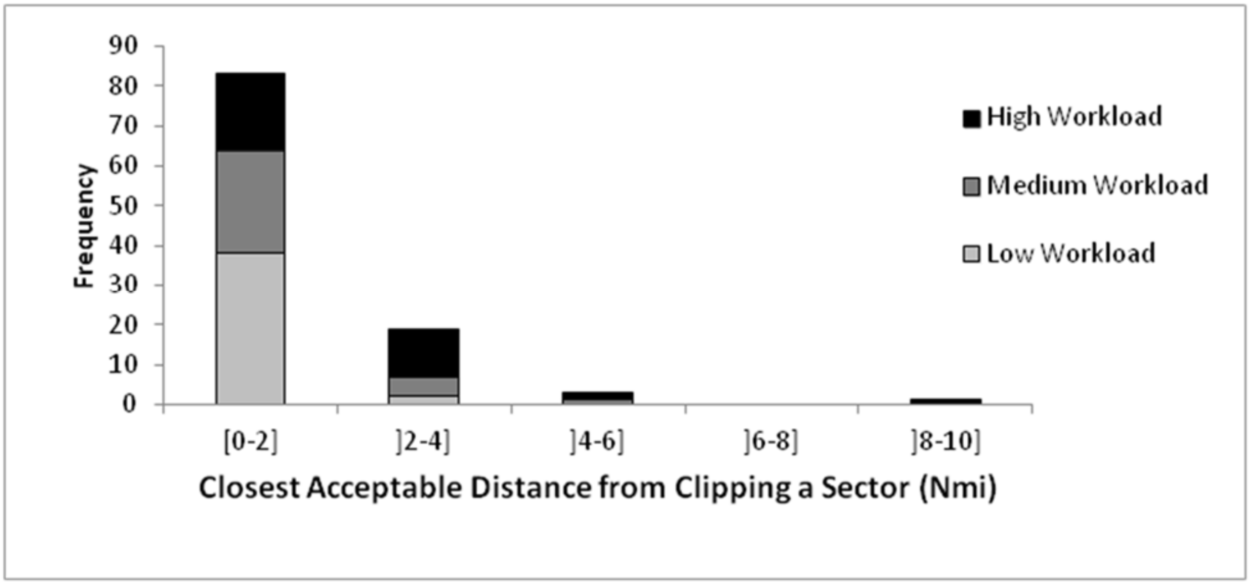


Figure 18 Distribution of closest acceptable distance from sector clipping.

Based on the analysis of the controllers' answers, it is recommended that a trajectory change request avoids a point out situation under high workload situations. This can be achieved by ensuring the required 2.5 nautical miles from the boundary between two sectors. However, based on the smaller emphasis of the controllers' answers on maintaining distance from sector clipping compared to when flying along boundaries, it is more acceptable that a trajectory change request does not take into consideration the clipping of a sector if that provides an optimal solution.

3.2.4 Time of request before handoff to sector

Controllers were asked how close to the handoff to the next sector they would still accept a request before telling the pilot to make the request to the next sector. Controllers are required to handoff an aircraft to the next sector when the aircraft is still in their airspace. If they forget to handoff an aircraft, the system will automatically flash the aircraft when closer than 3 nautical miles from the sector boundaries. If the controller of the next sector takes the handoff, he/she may not be talking to the aircraft yet, but the control of the aircraft has been taken. For this reason, it frequently happens that a pilot makes a request to a controller who is not in control of the aircraft anymore. This happens close to the handoff because pilots have no awareness of the sector boundaries. If a request is made in this situation, the controller has to call the controller of the next sector and ask to hand the aircraft back to her/him. The coordination requires additional workload. During the observations in both centers, multiple requests, not necessarily by the FT-2 aircraft, occurred close to the handoff status. Depending on the workload situation, controllers would either deny, asking to make the request to the next sector, or call back and accommodate the request.

A summary of the statistics resulting from the interviews for the handoff to sector factor is presented in Table 5. Most controllers replied with a range of values for each workload level, therefore the data are presented with an upper and lower level value as shown in Table 5. The number of controllers who answered the question is given in the last row of Table 5. While most controllers provided answers for the low workload levels, some controllers did not provide an answer for the moderate and high workload levels.

Table 5 Statistics of acceptable request time before handoff to another sector [Minutes].

	Low Workload		Medium Workload		High Workload	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
25th quartile	1.41	1.41	1.41	1.10	2.00	2.00
Median	2.00	2.82	2.00	2.00	3.00	4.00
Mean	2.39	2.79	2.50	2.72	3.65	4.00
Mode	2	2	2	0	5	5
75th quartile	3.00	4.00	3.00	4.18	5.00	5.00
Maximum	8.00	8.00	8.00	8.00	10.00	10.00
Standard deviation	1.71	1.97	1.93	2.20	1.94	2.07
Number of controllers	47	47	37	37	39	39

The acceptable time before handoff ranged between zero under low workload and ten minutes under high workload situations. Indicated by the mode in the table, the majority of controllers answered that they would accept a request up unitl 2 minutes from handoff under low workload. The mode of the time before handoff rose to 5 minutes under high workload. The median ranged between 2 minutes under low workload and 4 minutes under high workload. The upward trend in the mean acceptable time with the workload level can be seen in

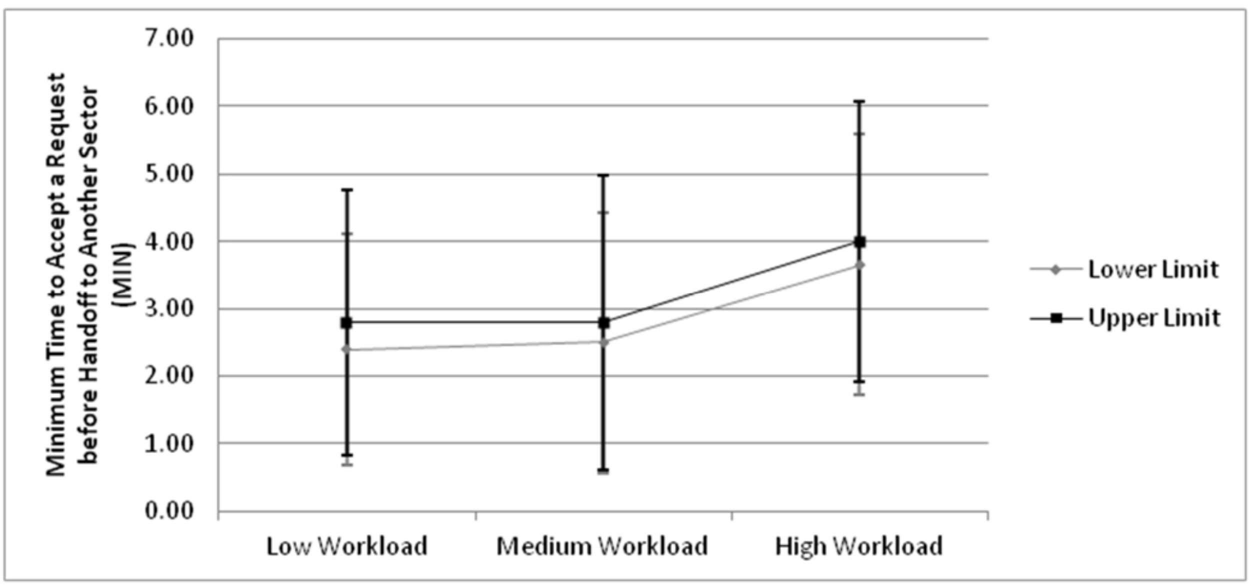


Figure 19. The mean increased from a range of 2.4-2.8 minutes under low workload to a range of 3.65-4 minutes under high workload. Similar results are supported by the distribution of the data shown in Figure 20, where longer times before handoff were required by the controllers under high workload.

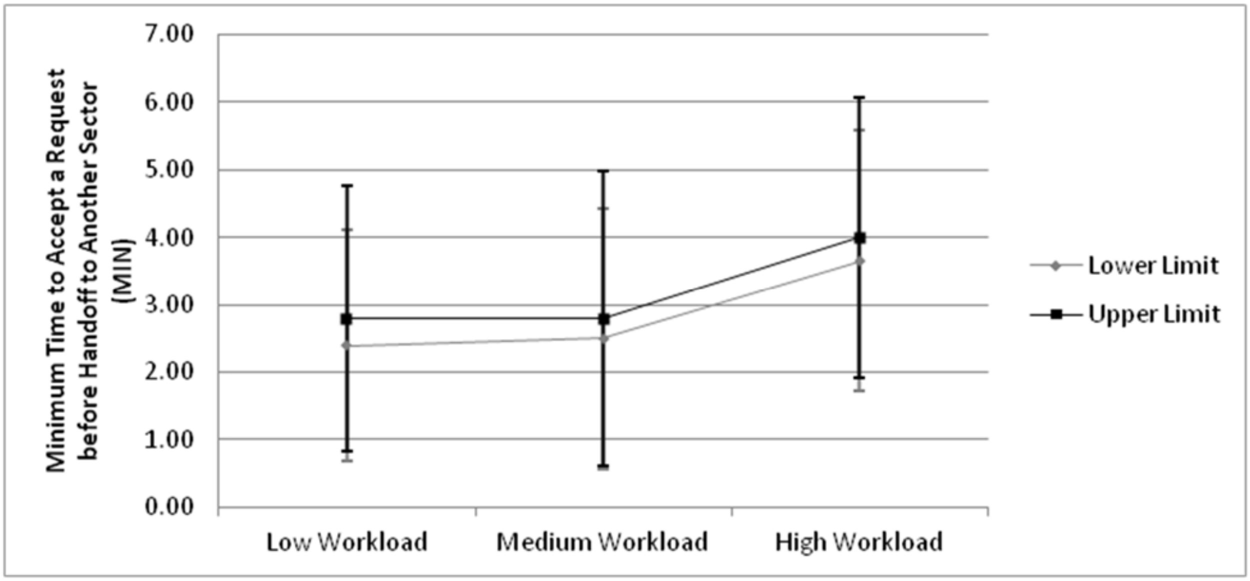


Figure 19 Minimum acceptable request time before handoff to another sector under different workload.

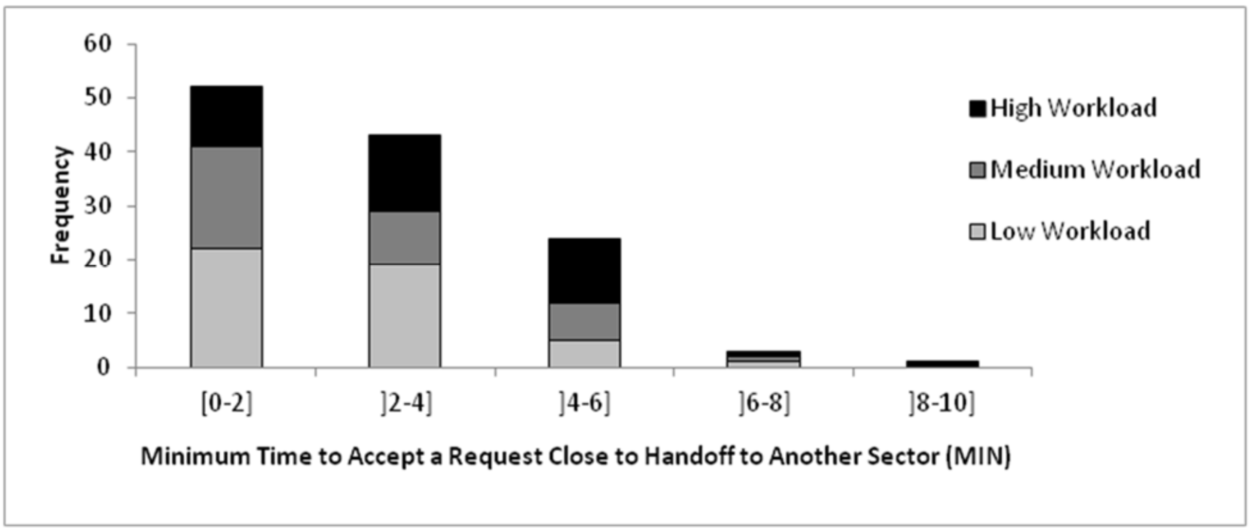


Figure 20 Distribution of minimum acceptable request time before handoff to another sector.

Based on the analysis of the controllers' answers, it is recommended to avoid making a trajectory change request when the aircraft is being handed off to the next sector at least under high workload situations. This can be achieved by including sector boundaries in the computation of the trajectory change request. The request desired time before handoff may be added to the threshold of three nautical miles before the sector boundary that is used by the automation to initiate an automated handoff.

3.2.5 Time of request after handoff from sector

Controllers were asked how soon after they receive the handoff from another sector they accept a pilot to request a trajectory change. Based on the controllers' answers, this factor was characterized by two

parameters: (1) the acceptable request time after the handoff and (2) the acceptable request distance after crossing the sector boundary. They are discussed below in this order.

(1) Request time after handoff

A summary of the statistics resulting from the time after handoff factor is presented in Table 6. Most controllers replied with a range of values for each workload level, therefore the data are presented with an upper and lower level value as shown in Table 6. The number of controllers who answered the question is given in the last row of Table 6. The low number of controllers who answered this question is explained by the fact that some controllers replied to this question only with a distance from the sector boundary instead of time after handoff; this parameter is captured next.

The acceptable time after handoff from another sector ranged between zero under low workload and two minutes under high workload conditions. The majority of controllers replied that they would like the pilot to ask for the trajectory change right away; this is shown by the mode being zero under all workload conditions. The median was also zero under all workload conditions. Because of the fewer data points the trend in the mean and standard deviation is not monotonic with workload as can be seen in Figure 21. Similar results are supported by the distribution of the data shown in Figure 22, where most controllers preferred knowing a request immediately after the handoff even under high workload.

Table 6 Statistics of acceptable request time after handoff from another sector [Minutes].

	Low Workload		Medium Workload		High Workload	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
25th quartile	0.00	0.00	0.00	0.00	0.00	0.00
Median	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.08	0.15	0.11	0.22	0.12	0.18
Mode	0	0	0	0	0	0
75th quartile	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	1.00	2.00	1.00	2.00	1.00	2.00
Standard deviation	0.26	0.52	0.33	0.67	0.33	0.53
Number of controllers	15	15	9	9	17	17

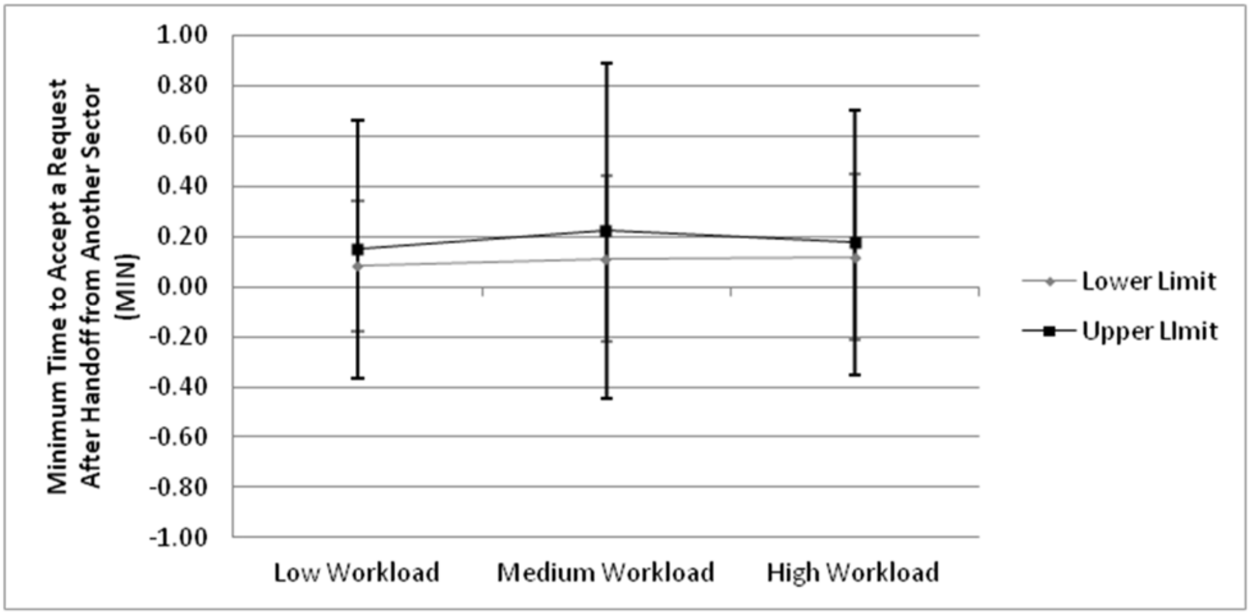


Figure 21 Minimum acceptable request time after handoff from another sector.

During the interviews most controllers explained that once an aircraft is handed off to their sector, even if the aircraft is not in their airspace, they prefer to hear the request right away. This helps them in planning for the request. If the requesting aircraft is not in his/her airspace yet, the controller has the option to delay the response. If the trajectory change request is urgent, for example for weather deviation, the controller has the option to call the controller of the previous sector and ask to obtain control for maneuvering the aircraft. In this way the controller can accommodate the request right away but with added workload. This situation arises again because of the lack of knowledge of the sector boundaries by the pilots.

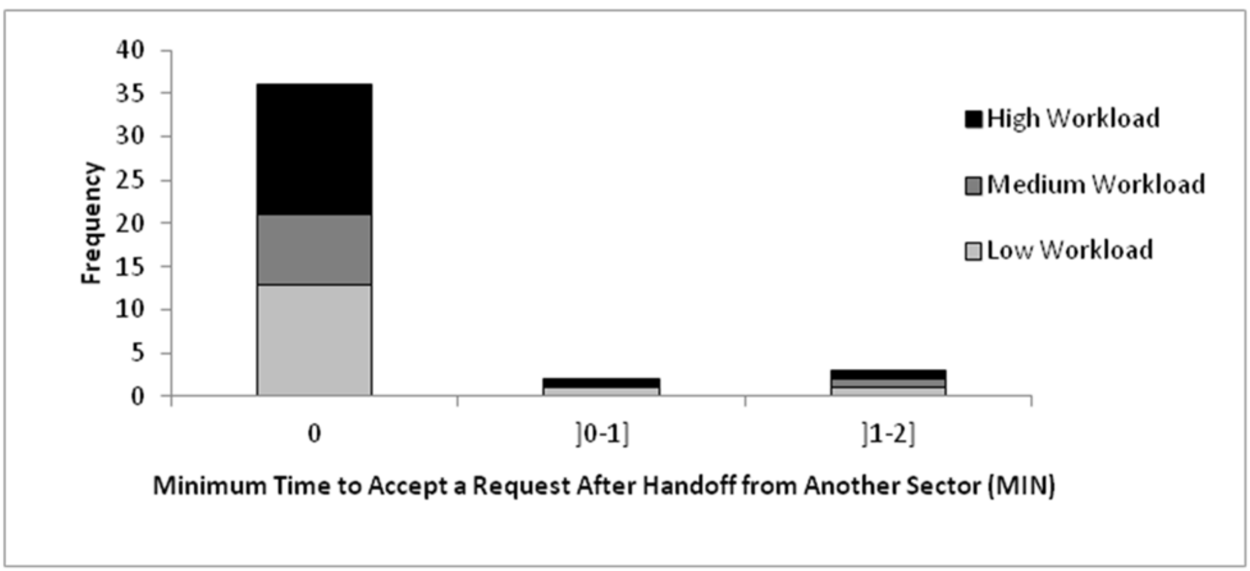


Figure 22 Distribution of minimum acceptable request time after handoff from another sector.

Based on the analysis of the controllers' answers, it is recommended that no delay factor be introduced to making a trajectory change request after handoff to a sector, because the controllers would like to hear the request as early as possible.

(2) Request distance prior to sector boundary after Handoff

Controllers were asked how soon after they receive the handoff from another sector they accept a pilot to request a trajectory change. Some of them answered with an acceptable distance relative to the boundary of their sector. The data presented in Table 7 represent these answers. Most controllers replied with a range of values for each workload level, therefore the data are presented with an upper and lower level value as shown in Table 7. The number of controllers who answered the question is given in the last row of Table 7. The low number of controllers that answered this question is explained by the fact that some controllers replied to this question with a time instead of a distance; this parameter was captured above.

Table 7 Statistics of acceptable request distance prior to sector boundary after handoff from another sector [Nmi].

	Low Workload		Medium Workload		High Workload	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
25th quartile	0.00	0.00	0.00	0.00	0.00	0.00
Median	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.28	0.28	0.20	0.25	0.07	0.07
Mode	0	0	0	0	0	0
75th quartile	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	5.00	5.00	2.50	3.00	1.00	1.00
Standard deviation	1.06	1.06	0.67	0.81	0.25	0.25
Number of controllers	27	27	22	22	30	30

The acceptable distance prior to the sector boundary after handoff from another sector ranged between zero under high workload and 5 nautical miles under low workload conditions. The majority of controllers replied that they would handle the trajectory change request once the aircraft is in their controlled airspace (zero distance from the boundary); this is shown by the mode being zero under all workload conditions. The median was also zero under all workload conditions.

A downward trend in the mean and standard deviation with workload can be seen in Figure 23. The mean acceptable distance before the sector boundary ranged between 0.28 nautical miles under low workload and almost zero (0.7) nautical miles under high workload. Most of the controllers replied that while they prefer to hear the request soon after the handoff, under high workload they would wait until the aircraft is in their airspace to handle the request. This is represented with a zero distance from the sector boundary. Under low workload, however, most of the controllers replied that they do not mind calling the previous controller and asking permission to handle the request, which is typically granted. Few of these controllers specified a distance however, while for most the answer remained qualitative. For this analysis, only the controllers that specified a distance were included, which explains the low mean distance of 0.28 miles under low workload. It is possible to assume that the acceptable distance for the controllers who did not provide a distance but mentioned that they would handle the request right after handoff is the automated handoff threshold distance of three miles. This would make the mean acceptable distance prior to the sector

boundary under low workload closer to three miles and reflect the willingness of the controllers to handle the request right after handoff even if the aircraft is outside their sector under low workload.

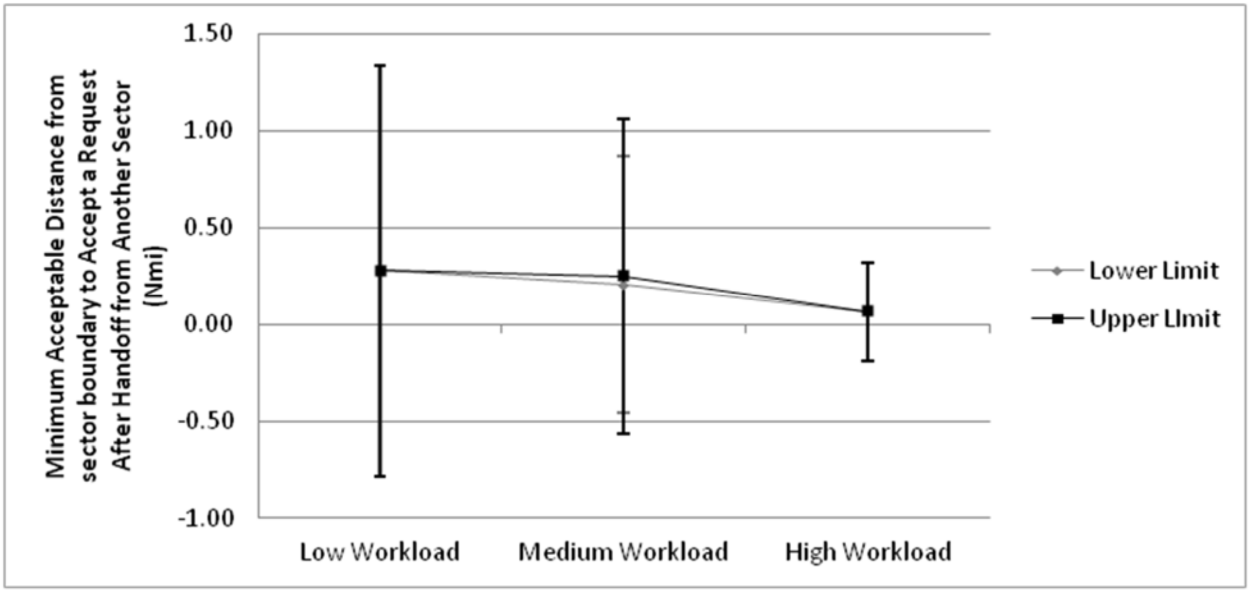


Figure 23 Minimum acceptable distance prior to sector boundary after handoff from another sector.

Similar results are supported by the distribution of the data shown in Figure 24, where shorter acceptable distances, closer to zero, were required by controllers under high workload, because they wait until the aircraft is in their airspace.

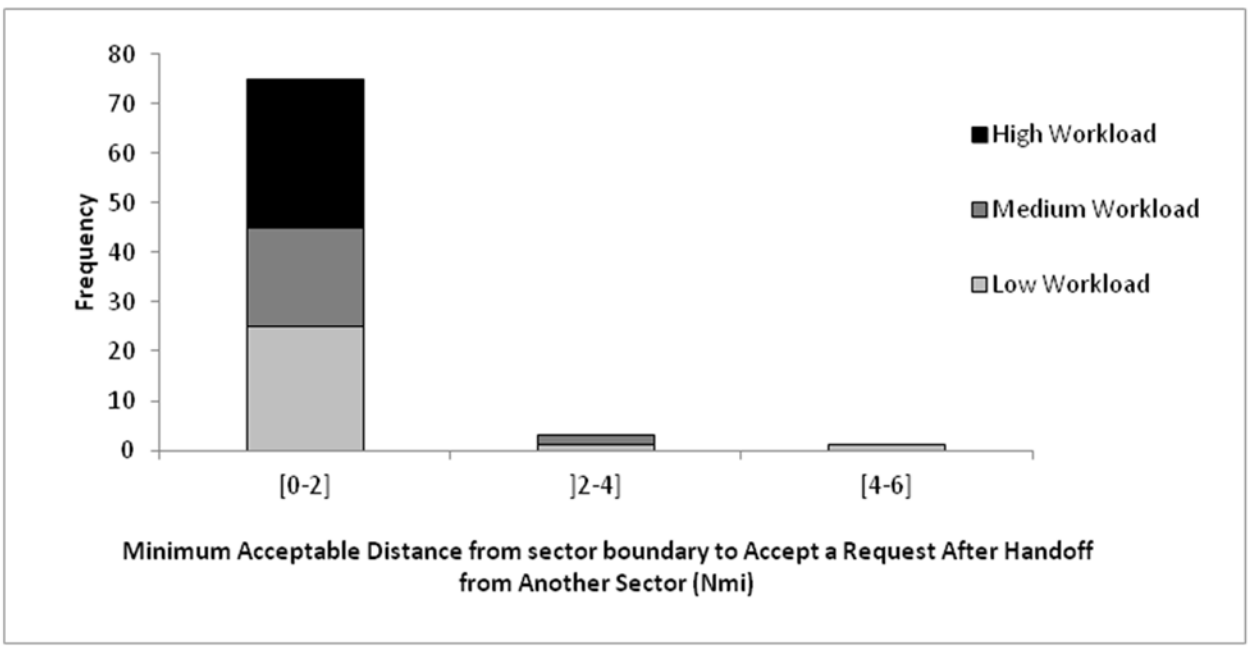


Figure 24 Distribution of minimum acceptable distance prior to sector boundary after handoff from another sector.

Based on the analysis of the controllers' answers, it is recommended that a trajectory change request that is near a sector boundary be designed assuming that it will not be handled until the aircraft crosses the sector boundary into the next sector, at least under high workload situations. This can be achieved by including sector boundaries in the computation of the trajectory change. For example, if the delay in handling the request due to the handoff makes the requested trajectory change suboptimal, alternative trajectory changes may be considered that take the delay into consideration.

3.2.6 Time of request before handoff to center

Controllers were asked how close to the handoff to another center they would still accept a request before telling the pilot to make the request to the next center. Similarly to the handoff to another sector inside the same center, controllers are required to handoff an aircraft to the next center when the aircraft is still in their airspace. With the current system, if they forget to handoff an aircraft, the system will automatically flash the aircraft when closer than 3 nautical miles from the sector boundaries. If the controller of the next center takes the handoff, he/she may not be talking to the aircraft yet, but the control on the aircraft has been taken. For this reason, it frequently happens that a pilot makes a request to a controller that is not in control of the aircraft anymore. This happens close to the handoff because pilots have no awareness of the sector and center boundaries. If a request is made in this situation, the controller has to call the controller of the next center and ask to handoff the aircraft back to her/him. The coordination requires additional workload. During the interviews controllers repeatedly stated that, while historically the handoff to another center had been more problematic, with the En Route Automation Modernization (ERAM) the handoff to another center is as simple as the handoff to another sector inside their own center. Hence most of the answers were similar in these two situations.

A summary of the statistics resulting from the interviews for the handoff to another center factor is presented in Table 8. Most controllers replied with a range of values for each workload level, therefore the data are presented with an upper and lower level value as shown in Table 8. The number of controllers who answered the question is given in the last row of Table 8. While most controllers provided answers for the low workload levels, some controllers did not provide an answer for the moderate and high workload level.

Table 8 Statistics of minimum acceptable request time before handoff to another center [Minutes].

	Low Workload		Medium Workload		High Workload	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Minimum	0.00	0.00	0.00	0.00	1.41	1.41
25th quartile	1.56	2.00	2.00	2.00	2.82	3.00
Median	2.82	3.00	2.82	3.00	4.00	4.00
Mean	2.60	3.04	2.99	3.45	3.99	4.47
Mode	2	4	3	3	5	4
75th quartile	4.00	4.00	4.12	4.62	5.00	5.00
Maximum	6.00	8.00	8.00	8.00	10.00	10.00
Standard deviation	1.60	1.91	1.81	2.09	1.81	1.90
Number of controllers	46	46	35	35	35	35

The acceptable time before handoff to another center ranged between zero under low workload and ten minutes under high workload situations. The majority of controllers under low workload answered that they would accept a request up until two minutes from handoff. The mode of the acceptable time rose to five

minutes under high workload. The median ranged between 2.8 under low workload and four minutes under high workload. The upward trend in the mean acceptable time with the workload level can be seen in Figure 25. It increases from a range of 2.6-3 minutes under low workload to a range of 4-4.5 minutes under high workload. The standard deviation is presented as error bars. Similar trend results are supported by the distribution of the data shown in Figure 26, where longer acceptable times were required by controllers under high workload.

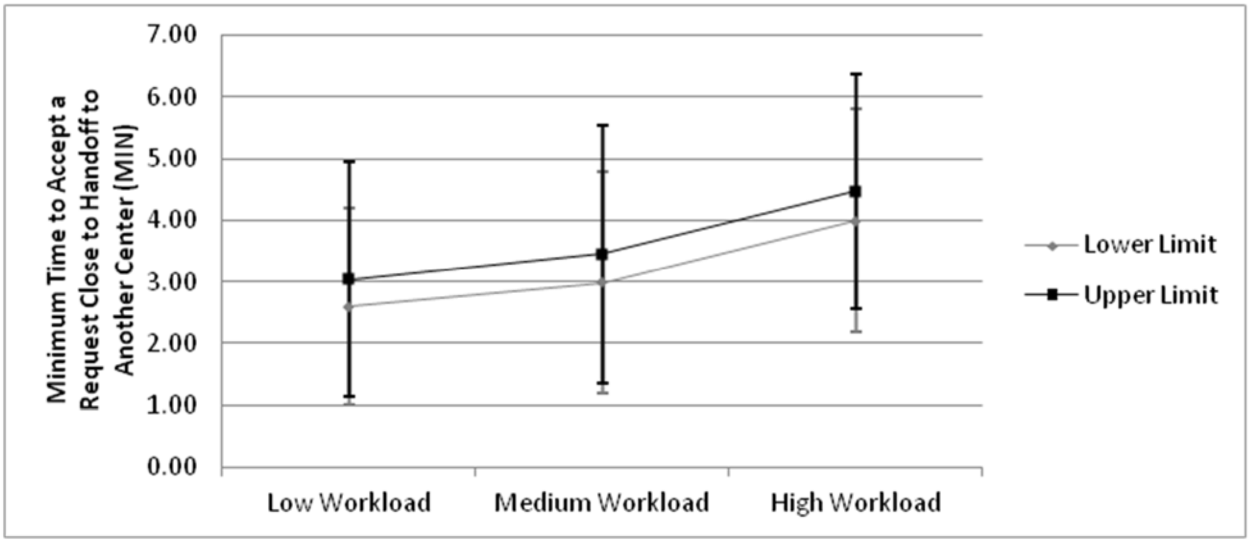


Figure 25 Minimum acceptable request time before handoff to another center under different workload.

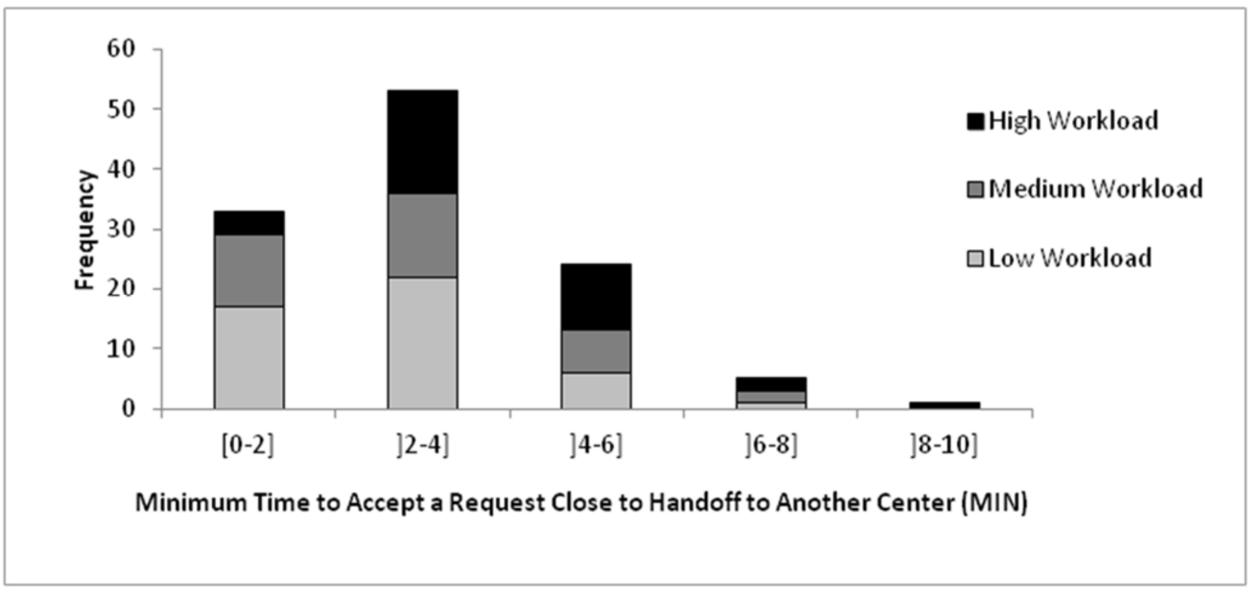


Figure 26 Distribution of minimum acceptable request time before handoff to another center.

Based on the analysis of the controllers' answers, it is recommended to avoid making trajectory change requests when the aircraft is being handed off to the next center at least under high workload situations. This can be achieved by including center boundaries in the computation of the trajectory change.

3.2.7 Request with additional waypoints

Controllers were asked how many additional waypoints in a trajectory change request they would accept. A summary of the statistics resulting from the interviews for the additional waypoints factor is presented in Table 9. Most controllers replied with a range of values for each workload level, therefore the data are presented with an upper and lower level value as shown in Table 9. The number of controllers who answered the question is given in the last row of Table 9. While most controllers provided answers for the low and high workload levels, some controllers did not provide an answer for the moderate workload level.

The acceptable number of additional waypoints ranged between a maximum of 20 under low workload and zero under high workload situations. It must be noted that the majority of controllers under low workload answered that they would accept any number of additional waypoints; this is shown in the second to last row of Table 9 which reports the number of controllers who replied with no limit on the number of additional waypoints. Most controllers under high workload conditions would accept only 2 additional waypoints as shown by the mode data. Under low workoad most would accept four to five additional waypoints. The median also ranged between two waypoints under high workload and five under low workload. The downward trend in mean acceptable number of additional waypoint and its standard deviation (presented as error bars) with the workload level can be seen in Figure 27. The mean ranged between seven waypoints under low workload and 2.5 under high workload. Similar results are supported by the distribution of the data shown in Figure 28, where most controllers required a small number of additional waypoints under high workload and a large number under lower workload levels.

Table 9 Statistics of acceptable number of additional waypoints.

	Low Workload		Medium Workload		High Workload	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Minimum	2.00	3.00	1.00	1.00	0.00	0.00
25th quartile	4.00	4.00	2.00	3.00	1.00	2.00
Median	5.00	5.00	3.00	4.00	2.00	2.00
Mean	7.44	7.67	2.96	3.59	2.10	2.49
Mode	5	4	3	5	2	2
75th quartile	8.00	8.00	4.00	5.00	3.00	3.00
Maximum	20.00	20.00	5.00	5.00	5.00	5.00
Standard deviation	5.83	5.68	1.29	1.31	1.26	1.14
Number of controllers quantitative	9	9	27	27	41	41
Number of controllers "no limit"	38		8		4	
Total number of controllers	47		35		45	

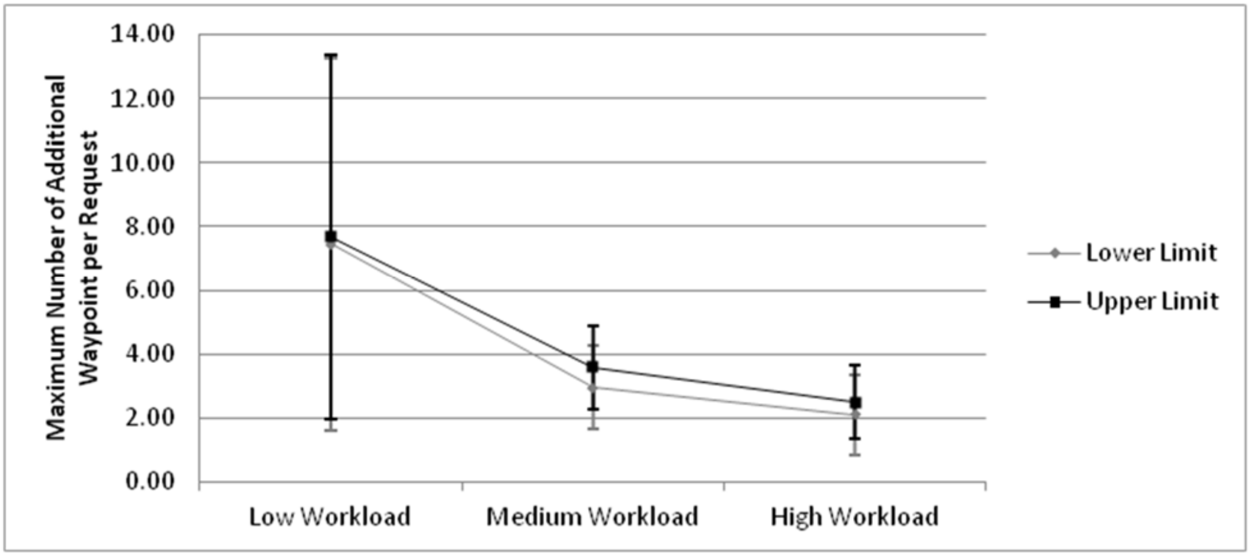


Figure 27 Maximum number of additional waypoint per request under different workload.

During the interviews, most controllers replied that under low workload levels they would not have any problem in changing the entire route of a flight. This is not reflected in Figure 27 where only the quantitative answers are plotted. Moreover, controllers also replied that the number of acceptable waypoints to be added to a route depends on how familiar they are with the waypoints. The more familiar they are the easier for them it is to add these waypoints to the route.

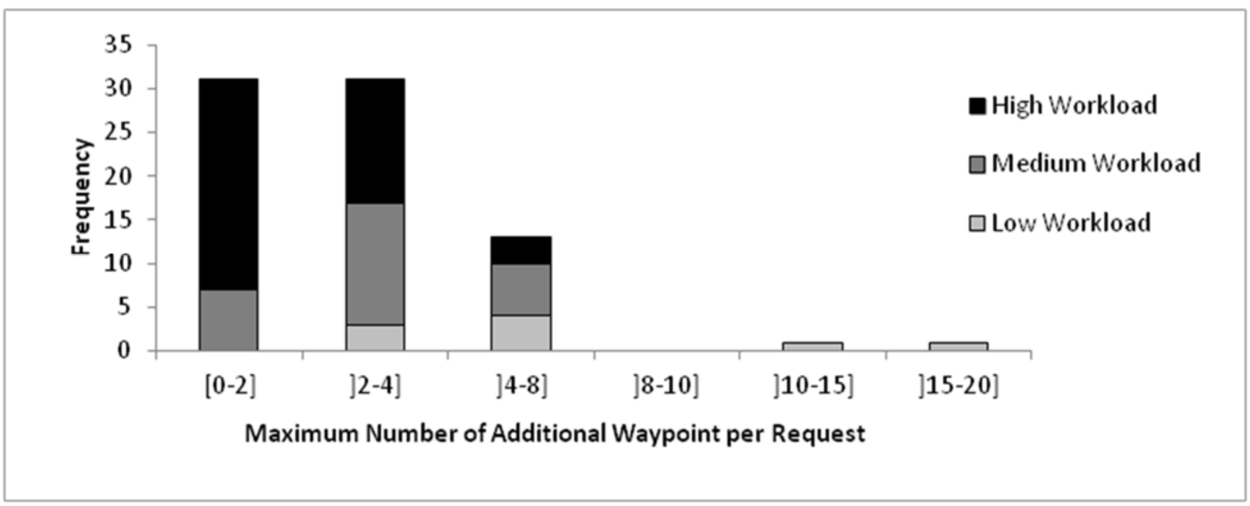


Figure 28 Distribution of acceptable number of additional waypoints.

Based on the analysis of the controllers' answers, it is recommended that only two additional waypoints be requested under high workload situations. Under low workload this limitation is not necessary; however, if the waypoints are not familiar the number should also be limited to five or seven.

3.2.8 Request with lateral and vertical maneuvers

Controllers were asked if a trajectory change request that includes lateral and vertical components is acceptable under different workload conditions. No quantitative data are presented for this factor because most controllers answered that the combination of lateral and vertical does not constitute a problem. Sometimes moving to a different altitude could be even advantageous for their workload. Some controllers replied that it can become an issue only if the altitude part of the request puts the aircraft in a different stratum of airspace. In that case they have to hand the aircraft off to another sector, either above or below them, adding to their workload. A few controllers answered that they might accommodate first one dimension of the request, for example the vertical, and then the lateral part.

Based on the analysis of the controller answers, it is recommended that no constraint on combining lateral and vertical dimensions be added when calculating trajectory change requests. Particular attention may be given to making altitude change requests that change the airspace stratum.

3.2.9 Request with unfamiliar waypoint types

Controllers were asked if a trajectory change request that includes E-Class (low altitude) waypoints is acceptable when flying class A airspace (en-route) under different workload conditions. No quantitative data are presented for this factor because almost all the controllers answered that as long as the waypoint's name is in the system it is not a problem which airspace class it belongs to. They also added that they don't know which category of airspace most of the waypoints belong to. Some controllers replied that the familiarity with the waypoints can be an issue. If a request includes a waypoint that they are not familiar with, their workload increases because they need to search for the waypoint's location to assess the impact of the trajectory change. This fact was also corroborated during the observations.

Based on the analysis of the controller answers, it is recommended that no constraint on the waypoints' airspace class be added when calculating trajectory change requests. In addition, if it is possible to distinguish familiar from unfamiliar waypoints, preference may be given to the ones that the controllers are familiar with. On the other hand, no problem is anticipated if the automation finds a benefit of using an unfamiliar waypoint as long as it is in the data base used by the controllers.

3.3 Event Observations

A total of 36 requests were made during the flight trial. A summary of the requests for each of the days and each flown route is presented in Table 10. Three of the requests were made in ZDC center airspace where no observers were present. Seven of the requests were made according to TAP advisories while the other requests were made according to scripted scenarios (the number of the scripted scenario is given in the table where applicable). One request on 6/11 was related to a weather event that was not scripted beforehand and was planned during the test. The table includes the factors that were intended in the scripted scenario and the factors that were invoked by the request (which may be different than or additional to the issues intended in the original scripted scenario). Eight of the requests were rejected due to the factors mentioned in the table. Nine were accepted with a delay; for example, some requests were rejected first and then accepted after the controller conducted needed coordination or resolved any traffic implications due to the request. The rest of the requests were accepted with no significant observed issues. The workload level that was observed is also stated for each of the requests as low, moderate or high.

Table 10 Summary of all the requests during FT2.

Day	Sector	O/D Pair	Scenario	Intended Factors	Response	Invoked Factors	Workload
6/9	ZDC 33	KPHF-KMGM	97	Center Intrusion	Accepted	Center intrusions	Low

Day	Sector	O/D Pair	Scenario	Intended Factors	Response	Invoked Factors	Workload
6/9	ZTL 20	KPHF-KMGM	105	E Class Waypoint	Accepted	Unfamiliar waypoint	Low
6/9	ZTL 20	KMGM-KPHF	126	2 Waypoints	Accepted	Unfamiliar waypoint	Low
6/11	ZDC	KPHF-KBHM	TAP	Combo	Accepted	N/A	N/A
6/11	ZTL 37	KPHF-KBHM	11	Combo	Accepted	Unfamiliar waypoint / Close to handoff / LOA violation	High
6/11	ZTL 22	KBHM-KPHF	N/A	Weather + 4 waypoints	Rejected	Weather / Next sector holding	Low
6/11	ZTL 34/32	KBHM-KPHF	130	Handoff	Delayed	Traffic / Unfamiliar waypoint	Moderate
6/11	ZTL 33	KBHM-KPHF	122	2 Waypoints	Accepted	Unfamiliar waypoint	Low
6/15	ZTL 33	KPHF-KMGM	98	2 Waypoints + Parallel Boundary	Accepted	Coordination / Point out	High
6/15	ZTL 20	KPHF-KMGM	31	Combo	Accepted	Unfamiliar waypoint	Low
6/15	ZTL 22	KPHF-KMGM	TAP	Handoff	Accepted	Coordination	Moderate
6/15	ZTL 37	KMGM-KPHF	143	Sector Intrusion	Accepted	Coordination / Sector clipping	
6/15	ZTL 50	KMGM-KPHF	TAP	Combo + 2 Waypoints	Delayed	Unfamiliar waypoint	Low
6/15	ZTL 42	KMGM-KPHF	141	2 Waypoints	Delayed	Unfamiliar waypoint	Moderate
6/15	ZDC	KMGM-KPHF	TAP	Handoff	Rejected	Handoff	
6/16	ZTL 42	KPHF-KBHM	2	Parallel Boundary	Rejected	Unfamiliar fix	Low
6/16	ZTL 42	KPHF-KBHM	6	Handoff	Rejected	After handoff	Low
6/16	ZTL 39	KPHF-KBHM	6	Handoff	Accepted	Coordination	Low
6/16	ZTL 39	KPHF-KBHM	33	Center Intrusion	Delayed	Coordination / Unfamiliar fix / Unfamiliar route	Moderate
6/16	ZTL 37	KPHF-KBHM	TAP	2 Waypoints	Delayed	Traffic / Unfamiliar waypoint	

Day	Sector	O/D Pair	Scenario	Intended Factors	Response	Invoked Factors	Workload
6/16	ZTL 22	KBHM-KPHF	113	Parallel Boundary	Delayed	Parallel boundary / Point out / Unfamiliar fix	Low
6/16	ZTL 34/32	KBHM-KPHF	116	Parallel Boundary	Rejected	Parallel boundary / Opposite traffic	Low
6/16	ZTL 33	KBHM-KPHF	TAP	2 Waypoints	Accepted	Unfamiliar waypoint / LOA violation	Low
6/16	ZTL 33	KBHM-KPHF	123	E Class Waypoint	Delayed	Coordination / Handoff / LOA violation	Low
6/18	ZJX 47	KPHF-KTPA	47	Parallel Boundary	Accepted	Next sector workload	Low
6/18	ZJX 50	KPHF-KTPA	53	Parallel Boundary	Accepted	Unfamiliar routing / Opposite traffic	Low
6/18	ZJX 77	KTPA-KPHF	174	SUA Proximity	Rejected	SUA intrusion	Moderate
6/18	ZJX 47	KTPA-KPHF	95	Handoff	Delayed	Handoff	Low
6/18	ZJX 66	KTPA-KPHF	86	2 Waypoints	Accepted		Moderate
6/18	ZJX 50	KTPA-KPHF	82	Center Intrusion	Rejected	Center intrusion / Unfamiliar waypoint	Low
6/20	ZJX 68	KPHF-KTPA	175	SUA Proximity	Accepted	Unfamiliar route / Opposite traffic / Traffic	Low
6/20	ZJX 68	KPHF-KTPA	TAP	N/A	Accepted	Unfamiliar waypoint / Opposite traffic	High
6/20	ZJX 50	KPHF-KTPA	60	Combo	Delayed	Traffic	High
6/20	ZJX 77	KTPA-KPHF	64	SUA Proximity	Accepted	SUA proximity	N/A
6/20	ZJX 66	KTPA-KPHF	92	2 Waypoints	Accepted	Coordination / Handoff / Point out	Moderate
6/20	ZJX 66	KTPA-KPHF	85	Handoff	Rejected	LOA violation / Sector intrusion	Moderate

Selected events are described below in more detail, highlighting specific factors and issues that resulted mainly in request rejection or in significant delay in request acceptance.

3.3.1 Events with proximity to SUA

Day: 6/18/2015

Flight: SYBB52 (TPA-PHF)

ARTCC: ZJX

Sectors: 77

Events: While flying in sector 77 at 21,000 feet, the test pilot requested to change the current route to fly to waypoint UPTON and then TYDOE (see Figure 29). UPTON was not in the route at the time of the request; the trajectory change would take the test aircraft off of its shortest route to destination. The scripted scenario (number 174) was intended to make the test aircraft fly close to the Moody MOA, a special use airspace that became active right before the request.

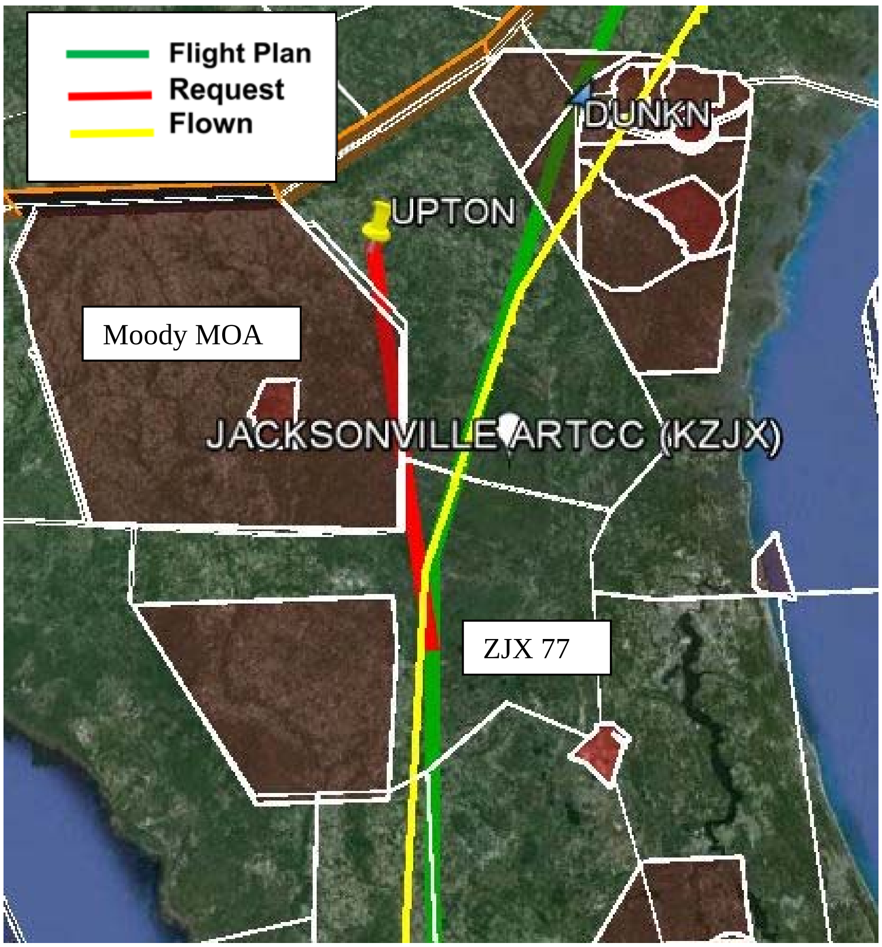


Figure 29 Scenario 174 – Incursion into active SUA (Map obtained from Google Earth).

This request tested the acceptability of a request to fly close to SUA boundaries. The controller in sector 77 was experiencing moderate to high workload at the time of the request due to some weather cells in his airspace. Before the test pilot made this request, ATC cleared him to go direct to TAY and to climb to a higher altitude. The pilot had to delay and asked to stay on current course and altitude in order to implement the scripted scenario. Once the test aircraft reached the position required for the scenario, the pilot requested to go direct to UPTON then TYDOE to reconnect to the route. After some clarification from the controller about the spelling of the waypoint, the controller rejected the request because the test flight would have

violated the Moody MOA’s airspace that just became active (see Figure 29). It was not possible to interview the controller who handled this request.

Based on this event, it is recommended that trajectory change requests maintain the minimum separation requirement of three nautical miles with active SUA’s at all times. Additional buffers may be added under high workload (See the previous section). Under low workload and SUA activity it may be possible to request slight incursion into an SUA if necessary.

3.3.2 Events with flying along sector boundaries

Day: 6/18/2015

Flight: SYBB51 (PHF-TPA)

ARTCC: ZJX

Sectors: 47

Events: While flying in sector 47, the test pilot requested to change the current route to fly to waypoint DUNKN and then keep the rest of the route unchanged. DUNKN was in the route at the time of the request; the request created a shortcut. The scripted scenario (number 47) was intended to make the test aircraft fly along the boundaries between sectors 66 and 68 (See Figure 30). This request tested the acceptability of a request to fly along sector boundaries, which requires controllers to perform a point out. The controller in sector 47 was experiencing low workload at the time of the request. Before the test pilot made this request, ATC cleared him to go direct to TAY, a waypoint further down than DUNKN. The pilot had to delay and asked to stay on current course in order to implement the scripted scenario. Once the test aircraft reached the position required for the scenario, the pilot requested to go direct to DUNKN. The controller accepted the request right away. The controller decided to hand off the test aircraft to sector 68 and point it out to sector 66 because it flew right on the border between these two sectors (see Figure 30). The controller displayed the route several times after granting the request. In the follow up interview, he explained that he was considering issuing a slight left turn to avoid sector 66 and reduce workload. The controller explained that sector 68 was not an issue because the aircraft was going there in any case; however, for sector 66 it is an extra effort to have to monitor the aircraft (with point out) if it is on the boundary. He also mentioned that the workload of sector 66 was not high at the time; otherwise he would have waited few minutes before granting the request to ensure that the aircraft is firmly in sector 68. The controller also explained that the decision is partially dependent on the aircraft performance: slow aircraft are kept on route because it is easier to merge them with other flows but a fast aircraft is typically given a short cut.

Figure 30 Scenario 47 – request along boundaries (Map obtained from Google Earth).

Day: 6/18/2015

Flight: SYBB51 (PHF-TPA)

ARTCC: ZJX

Sectors: 50

Events: While flying in sector 50, the test pilot requested to change the current route to fly to waypoints CRG and OLENE. These waypoints were not in the route at the time of the request. The scripted scenario (number 53) was intended to make the test aircraft fly along the boundaries between sectors 50 and 68 (see Figure 31).

Figure 31 Scenario 53 – request along boundaries (Map obtained from Google Earth).

This request tested the acceptability of a request to fly along sector boundaries which requires controllers to perform a point out. The controller in sector 50 was experiencing low workload at the time of the request. Before the test pilot made this request, ATC cleared him to go direct to JAYJA. The pilot had to delay and asked to stay on current course in order to implement the script. Once the test aircraft reached the position required for the scenario, the pilot requested to go direct to CRG and then to OLENE. The controller had to coordinate with his supervisor before accepting the request. The request took the test aircraft farther away from the destination TPA. The controller thought the request was very strange also because it took the test aircraft outside of the preferred routes to land in TPA (see Figure 31). The test pilot told the controller that they were testing some navigational equipment. After that the controller accepted the request. The whole process took more than one minute. Without the navigational equipment excuse, most likely this request would have been rejected not because of the sector boundaries issue (a point out to sector 68 was necessary) but because it violated the preferred routes into TPA airport. TPA is a medium airport and the traffic is routed in a fairly strict way.

Based on these events it is recommended not to add any restriction on flying along sector boundaries to the trajectory change calculations, except if the controllers are in high workload.

3.3.3 Events with intrusion in adjacent center

Day: 6/16/2015

Flight: SYBB41 (PHF-BHM)

ARTCC: ZTL

Sector: 39

Event: While flying in sector 39, the test flight pilot requested to change the current route to fly to waypoint BAZOO and then reconnect to the current route at CALCO. BAZOO was not in the test flight's route at the time of the request. This waypoint is in Memphis (ZME) ARTCC airspace (see Figure 32).

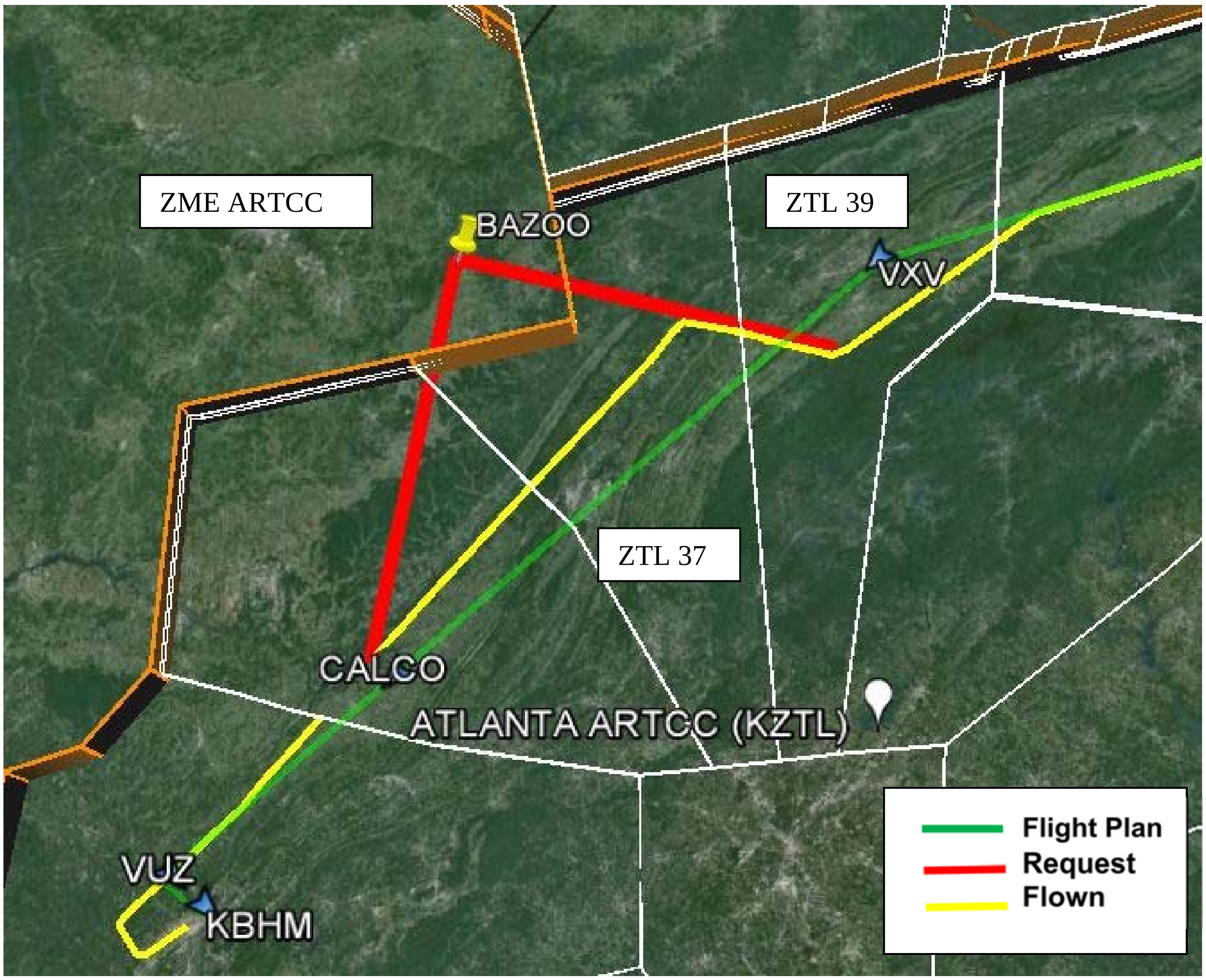


Figure 32 Scenario 32 – request to intrude into another center (Map obtained from Google Earth).

The scripted scenario (number 32) was intended to test the acceptability of requests that go outside the current ARTCC for a short period of time. The controller in sector 39 was experiencing moderate to low workload and was assisted by a D-side controller at the time of the request. Once the controller identified the location of BAZOO, he deemed the request strange because it would take the test aircraft out of its way to land in BHM (see Figure 32). Moreover the request would have brought the test flight into ZME airspace requiring center to center coordination. The D-side controller coordinated with ZME to confirm it was OK,

but also with sector 37 because the test flight's trajectory would significantly change. The second observer was shadowing sector 37 at the time. Sector 37's controller approved the request commenting that the route was unfamiliar but it is acceptable by him and the intrusion into ZME is not an issue with ERAM. After all the coordination was completed ATC accepted the request. The process, from the pilot's request to the ATC acceptance, took less than two minutes. During the interview the controller said that since he had the D-side's help, even if he deemed the request strange, he accepted it. He also added that sometimes aircraft request strange changes to test their navigation equipment. The controller also added that if the additional waypoint was further into ZME airspace he would have to reject the request because of letters of agreements (LOAs). In giving shortcuts, controllers are restricted in how far into other centers' airspace they can accommodate because of the LOAs.

Based on this event it is recommended to consider adding LOA information when calculating a trajectory change.

Day: 6/18/2015

Flight: SYBB52 (TPA-PHF)

ARTCC: ZJX

Sector: 50

Event: As the aircraft was flying in sector 50, the pilot made a request to make route change through GRADY. The controller had low workload at the time, handling about five aircraft. The controller was not familiar with the waypoint GRADY and denied the request. He indicated in the interview that he looked for it and it was not there. He also thought that the waypoint is in ZTL and that it would not work because of intruding into another center.

As a result it is recommended that center intrusion is avoided in pilot requests, particularly if violating LOAs.

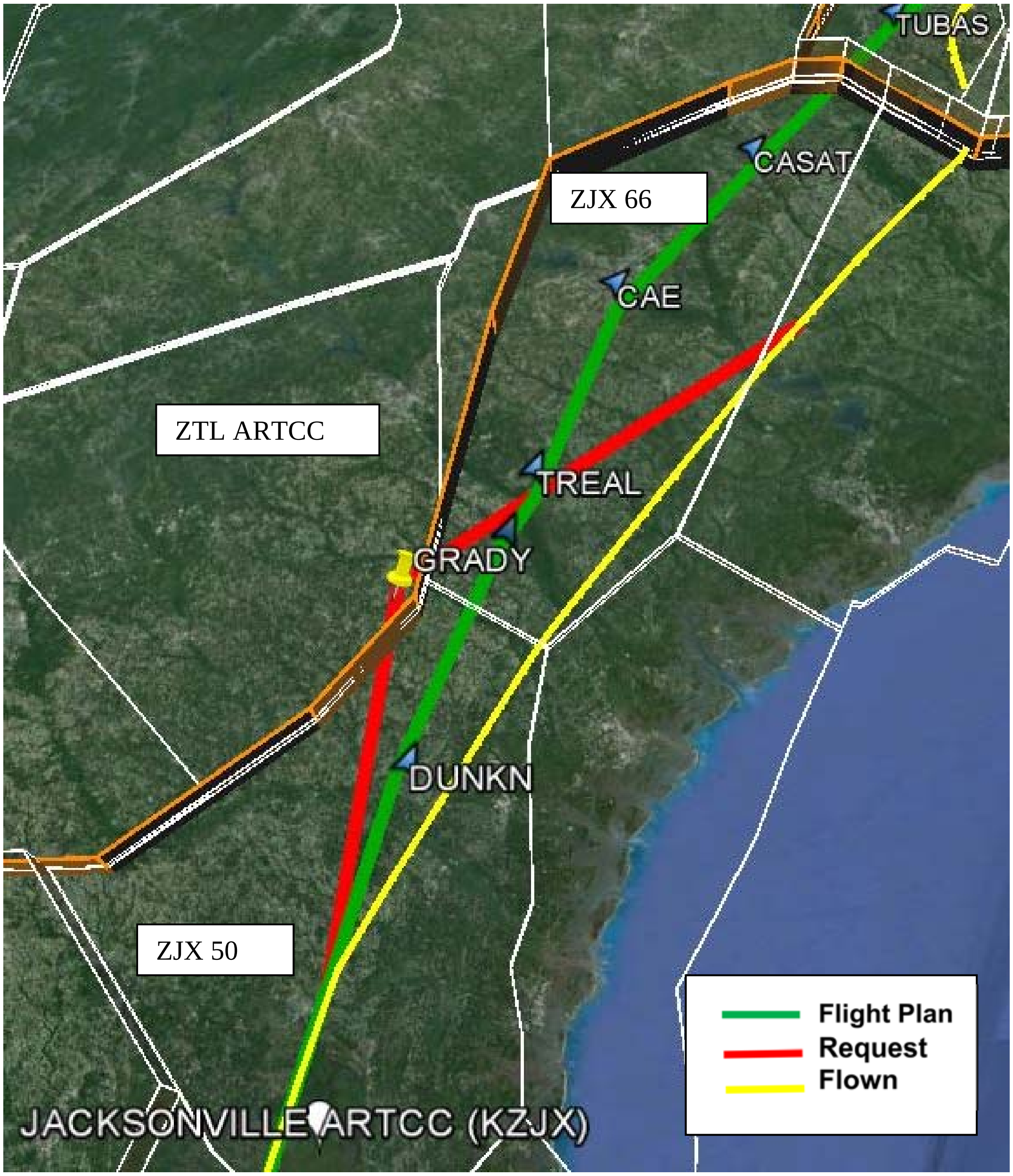


Figure 33 Scenario 82 – request intrudes into another center (Map obtained from Google Earth).

3.3.4 Events with unfamiliar waypoint types

Day: 6/11/2015

Flight: SYBB21 (PHF-BHM)

ARTCC: ZTL

Sector: 37

Event: While flying at 30,000 feet in sector 37, the test flight pilot requested to change the current route to fly to waypoints WODDY then VUZ and to climb to 32,000 feet. Those two waypoints were not in the test flight's route at the time of the request. The scripted scenario (number 11) was originally intended to test

the acceptability of requests with a combination of lateral and vertical components. The controller in sector 37 at the time of the request was experiencing moderate to low workload. When the request was made his workload increased suddenly because he was unfamiliar with the location of the waypoint WODDY, and therefore he did not know what impact on the route the change would have. For this reason, he asked the pilot to spell the name of the waypoint and confirmed that it was WODDY again. After looking the waypoint up, he accepted the pilot's request. The process, from the pilot's request to the ATC acceptance, took more than one minute. During the interview, the controller said that he did not think there was anything strange about the request but reiterated that being unfamiliar with waypoint WODDY caused his workload to increase suddenly.

Day: 6/16/2015

Flight: SYBB41 (PHF-BHM)

ARTCC: ZTL

Sector: 42

Event: While flying in sector 42, the test flight pilot requested to change the current route and fly to waypoint LORNN and then reconnect to the route at CALCO. The scripted scenario (number 2) was originally intended to make the test aircraft fly along the boundaries between sector 42 and sector 50 testing the acceptability of a request that flies parallel to sector boundaries. The controller of sector 42 was under low workload at the time of the request. The controller did not recognize LORNN so he asked to repeat the name and then to spell it. He told the pilot that he would get back to him in two minutes. The controller offered VUZ as an alternative waypoint before CALCO. When the pilot confirmed his preference for LORNN, the controller again said he would get back to him in two minutes. The controller could not find LORNN in the system and therefore had to reject the request. The process, from the pilot's request to the ATC rejection, lasted about four minutes. Due to schedule, the controller could not be interviewed. It was confirmed that LORNN is in the database of waypoints, it was spelled correctly by the pilot but the controller probably made an error in entering the name in the system. This event showed again how unfamiliar waypoints can cause issues in the acceptability of pilots' requests.

Day: 6/16/2015

Flight: SYBB41 (PHF-BHM)

ARTCC: ZTL

Sector: 37

Event: While flying in sector 37, the test flight pilot requested to change the current route and fly to waypoint SHNYD and then reconnect to the route at CALCO. The controller of sector 37 was under low workload at the time of the request. The request created a traffic conflict and the controller had to wait for a Southwest Airlines (SWA) flight to clear an altitude before granting the request. The controller did not recognize SHNYD and commented that it is no longer being used. He proposed VUZ to the pilot, commenting that they will want him on VUZ eventually for the destination arrival. The pilot accepted VUZ.

Based on these events and similar ones that occurred during the flight trial, it is recommended to avoid including unfamiliar waypoints in the trajectory change requests and to maintain the common arrival routes to their destination.

3.3.5 Events during handoff

Day: 6/16/2015

Flight: SYBB41 (PHF-BHM)

ARTCC: ZTL

Sectors: 42/39

Event: As the test flight approached the boundary of Sector 42, the pilot made a request to fly direct CALCO. The controller had already flashed the aircraft to the controller of the next sector 39. The controller rejected the request and instructed the pilot to contact the next sector with the request. In the follow up interview, the controller commented that the request was made too close to the boundary and hence the aircraft was already flashed to the next controller. He commented that typically if a request is made 2-3 minutes from the boundary it may be deferred to the next controller. The second observer already monitoring sector 39 captured the request made from the sector 39 controller after the handoff. The aircraft was still in the sector 42 airspace at the time of the request. Therefore, the controller coordinated with the controller of sector 42 before granting the request.

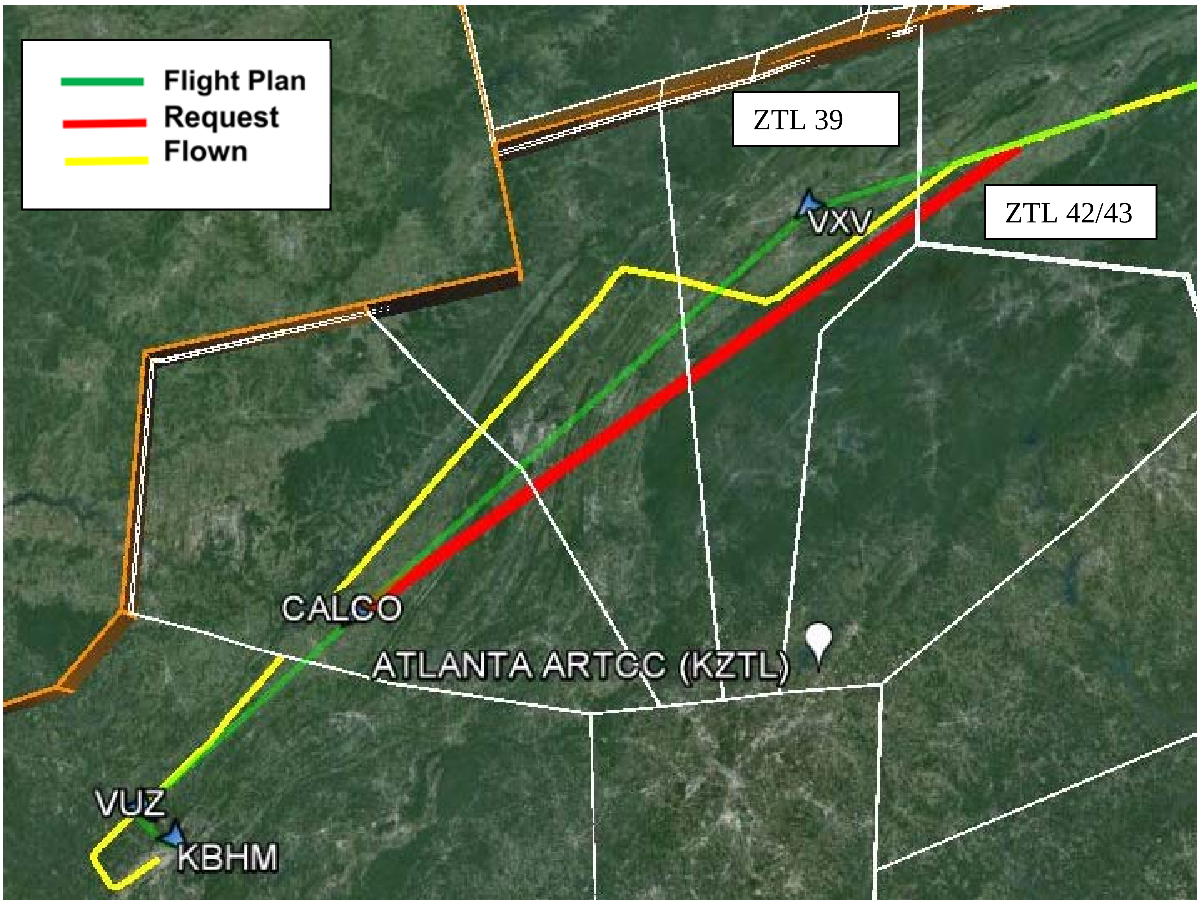


Figure 34 Scenario 6 – request during handoff (Map obtained from Google Earth).

This event highlights a common behavior that was observed in the flight trial and mentioned in the interviews. Namely if the aircraft is handed off but is still in the airspace of the previous sector, the controller has to coordinate with the previous controller in order to grant the request. Based on this and other similar events during the flight trial, it is recommended that if an aircraft is close to the sector boundary, the pilot request should be made from the next controller, and preferably after the aircraft had crossed the boundary into the next sector to avoid needed coordination between controllers.

Day: 6/16/2015

Flight: SYBB42 (BHM-PHF)

ARTCC: ZTL

Sectors: 33

Event: As the flight was flying through sector 33 approaching the ZDC boundary, the pilot made a route change request to fly to KATZN and then direct PHF. The workload of the controller was low with about five aircraft, but was busy at the time of the request and asked the pilot to stand by. The aircraft was already handed off to ZDC sector 32 but sector 33 in ZTL still had the communication with the aircraft. In the interview, the controller pointed out that in this case only ZDC can enter the route in the computer and therefore he had to ask for approval (APREQ) from ZDC. If approved, then he can put the route change in the computer. Another complication was that the request involved a sharp turn in ZDC and was off the required arrival route per the LOA. However, the aircraft was already off the LOA route because of a previous request that was accepted and therefore, the controller explained that he did not feel it was an issue. The controller explained that he had the option to coordinate with ZDC sector 32 and then sector 32 would coordinate with the next ZDC sector 36. The journey of the aircraft in sector 32 was short and therefore the controller called both ZDC sectors 32 and 36. In this case ZDC, sector 32 flashed the aircraft directly to sector 36. The controller explained that he should have deferred the request to be made from the ZDC controller. The controller was a trainee and his trainer at the time allowed him to make these decisions, but pointed out later that it is better in this case to defer to ZDC.

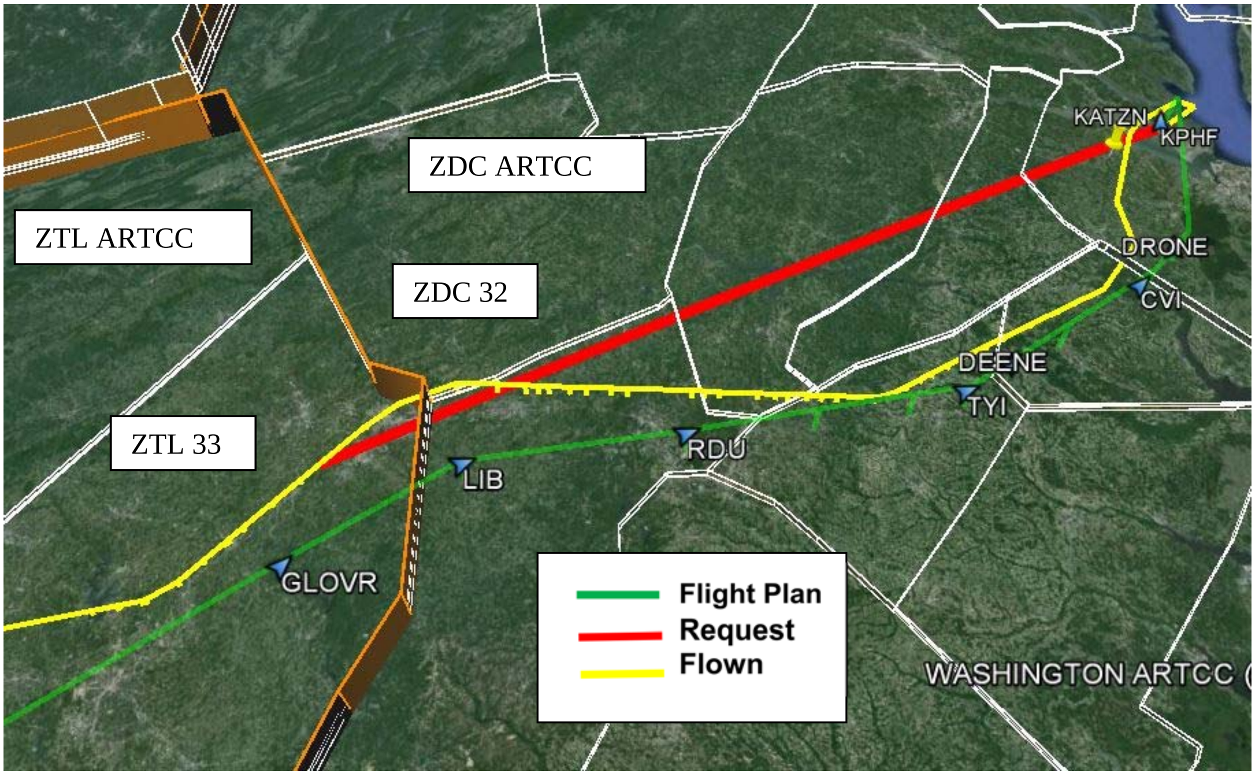


Figure 35 TAP request – request during handoff (Map obtained from Google Earth).

This event shows a variation on handling the request during the handoff, where the controller under low workload may try to help the following controllers and handle the request rather than reject it and defer it to them. It is however, still recommended that if the sector boundaries are known to the aircraft that a pilot request is made from a controller after crossing the sector boundary to avoid the added coordination between the controllers.

Day: 6/18/2015

Flight: SYBB52 (TPA-PHF)

ARTCC: ZJX

Sector: 50

Event: As the aircraft approached the boundary of sector 50, the pilot made a request to change altitude to flight level 33. First the controller rejected the request because even though he had communication, the aircraft was not yet in his airspace and coordination would have been required. Once the aircraft was in the airspace the controller accepted the request and granted the altitude. The workload of the controller was low at the time of the request handling about five aircraft.

This event demonstrates clearly the tendency of controllers to prefer handling the pilot requests after the aircraft is in their airspace to avoid the need for coordination.

Based on these and other similar events during the flight trial, it is recommended that if an aircraft is close to the sector boundary, the pilot request should be made from the next controller, and preferably after the aircraft had crossed the boundary into the next sector to avoid needed coordination between controllers.

3.3.6 Events with weather interaction

Day: 6/11/2015

Flight: SYBB22 (BHM-PHF)

ARTCC: ZTL

Sector: 22

Event: Weather activity was affecting the northern part of ZTL. A request that results in interaction with the weather was scripted in real time and communicated to the TAP engineer before takeoff. The request was a route change that took the flight to GQO VXV HMV PSK RDU reconnecting at RDU, which was a multiple waypoint deviation from the original route (see Figure 36). This was an off nominal event not originally scripted nor planned in the test matrix. The request was made by the test pilot right after the aircraft was handed off to the sector 22 controller. The controller's workload at the time was low and was only monitoring three aircraft with no weather activity in sector 22. Despite the long request, the controller examined the route in the system and accepted it, without the need for a D-side and while the aircraft was still in the previous sector. The controller advised the pilot of weather over the next twenty miles. As the test flight proceeded along the reroute north towards sector 06 (as can be seen in Figure 36), the tracker of sector 06 called the controller and said that the sector is in holding and cannot take the flight. In the follow up interview, the controller of sector 06 explained that the sector was impacted by weather while handling arrivals to ATL. The weather caused traffic saturation because it shut down some of the available holding patterns that the sector has (see Figure 36). The sector was experiencing high workload with 25 aircraft and had a D-side open and a tracker to provide additional assistance. At the same time, the terminal radar control (TRACON) airspace of ATL was also impacted by weather and was changing the available routes frequently and unpredictably causing confusion for sector 06. As a result, the sector 06 controller decided to shut off the arrivals and go into holding, shutting off the ZME feed as well, until the proper routing is established. This was the reason the test flight was denied access to sector 06. The controller of sector 22 immediately received help from the supervisor and a D-side that was opened. The test flight was given a vector to turn to heading 090 immediately while waiting for a resolution (see the right turn in the actual track in Figure 36). The team came up with a resolution to keep the flight on that heading flying along the boundaries of sector 22 with sectors 37 and 39 with point outs to these sectors. Then the flight was handed off to sector 50. The interview with the controller of sector 22 indicated that none of this would have been an issue without weather and that better coordination with sector 06 should have been performed.

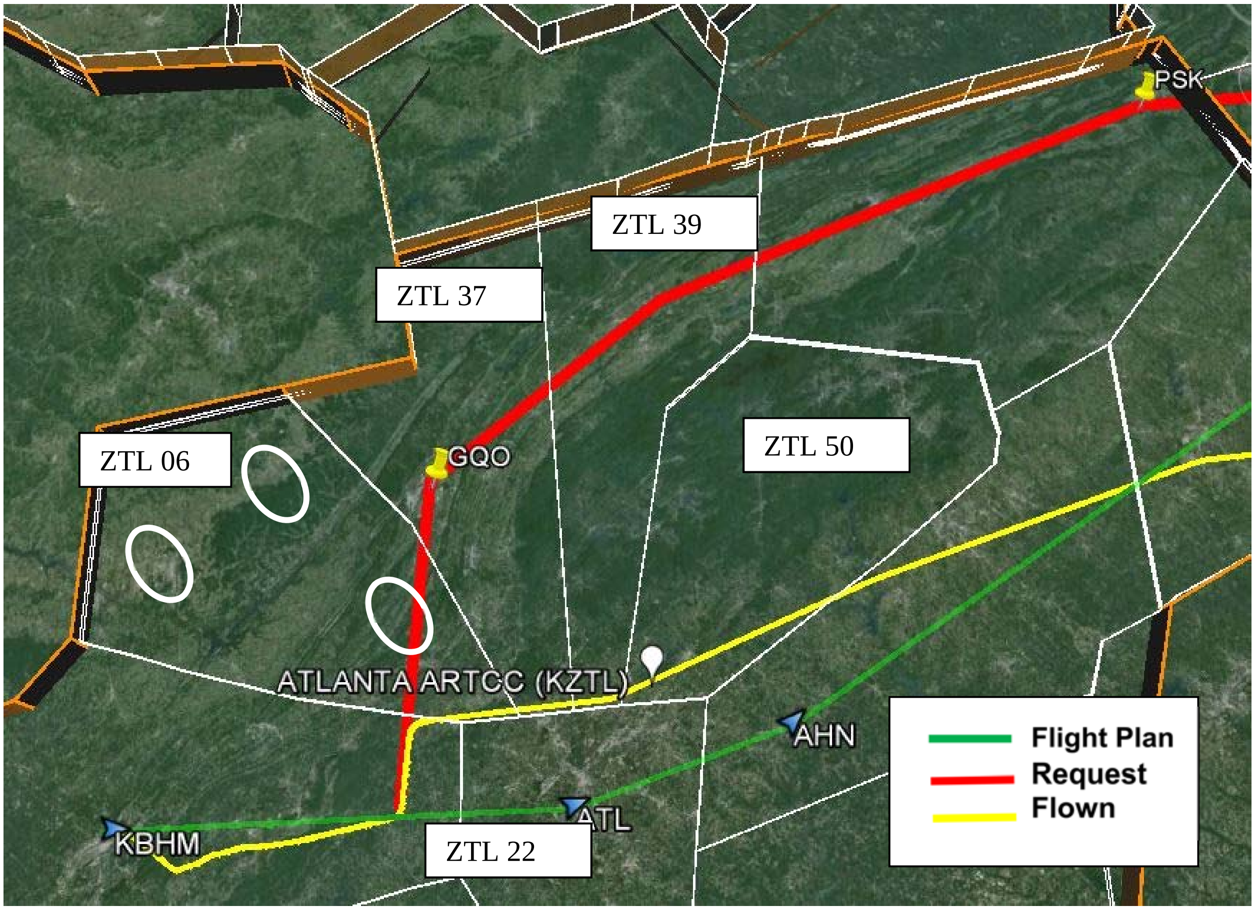


Figure 36 Weather event (Map obtained from Google Earth).

This event indicates the exponentially increased complexity when pilot requests interact with weather, particularly when combined with high volume traffic flows such as the ATL arrival stream. It shows in particular the need for coordination between different impacted sectors, where in some cases the sector handling the request may not be the one impacted by the weather. While only one weather event was observed, the safety concerns raised by this event lead to the recommendation that weather interactions should be avoided in making pilot requests, particularly when combined with high traffic interactions.

3.3.7 Events with interaction with arrival stream

Day: 6/16/2015

Flight: SYBB42 (BHM-PHF)

ARTCC: ZTL

Sectors: 22 and 34/32

Events: While the aircraft was flying in sector 22, the test flight pilot made a request for a route change with multiple waypoints MURKY GLOVR which were not on the original route (see Figure 37). The request resulted in flying along the boundaries between sectors 50 and sector 34/32 (two combined sectors) which was scenario 113. While sector 50 was handling the busiest arrival flow into ATL, the controller accepted the request with a point out to sector 50. The controller commented in the interview that the workload has to be very high to reject such a request despite the point out. Then, the aircraft was flying across the boundaries between sector 34/32 and sector 50 and was controlled by the controller of 34/32 and

pointed out to the controller of sector 50 (see Figure 38). The pilot made another request to fly to waypoints BURLS and then to LIB which was in the original flight plan route. This was scenario request number 116. The controller was under low workload conditions. As soon as the controller confirmed the two additional waypoints, he immediately rejected the request, replying that it would put the aircraft on opposite direction with ATL arrivals that use sector 50 to transition into lower altitudes. The arrival stream is indicated in Figure 38 by the large orange arrow. Controllers repeatedly stated that some sectors, especially in ZTL, have a prevalent direction from or to major airports. For this reason, they avoid maneuvering traffic against these major flows.

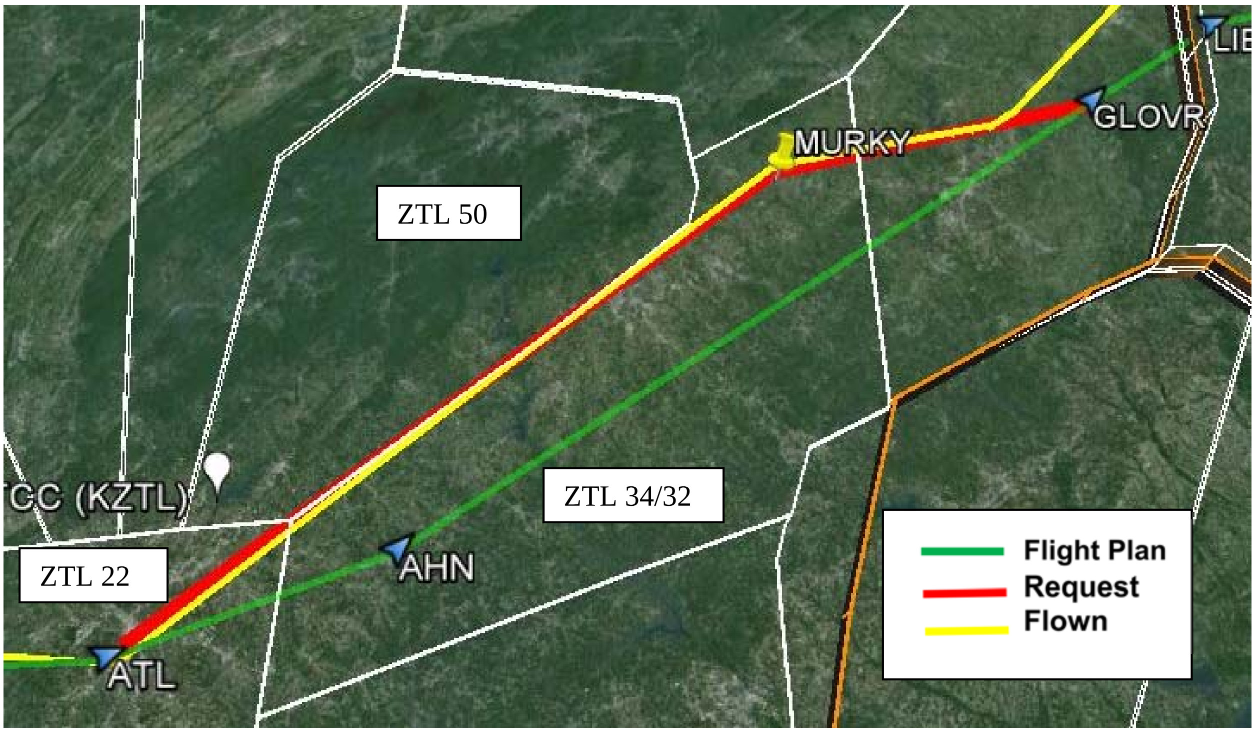


Figure 37 Scenario 113 – request to fly along sector boundaries (Map obtained from Google Earth).

As a result it is recommended that interacting with major arrival streams into large airports be avoided in pilot requests.

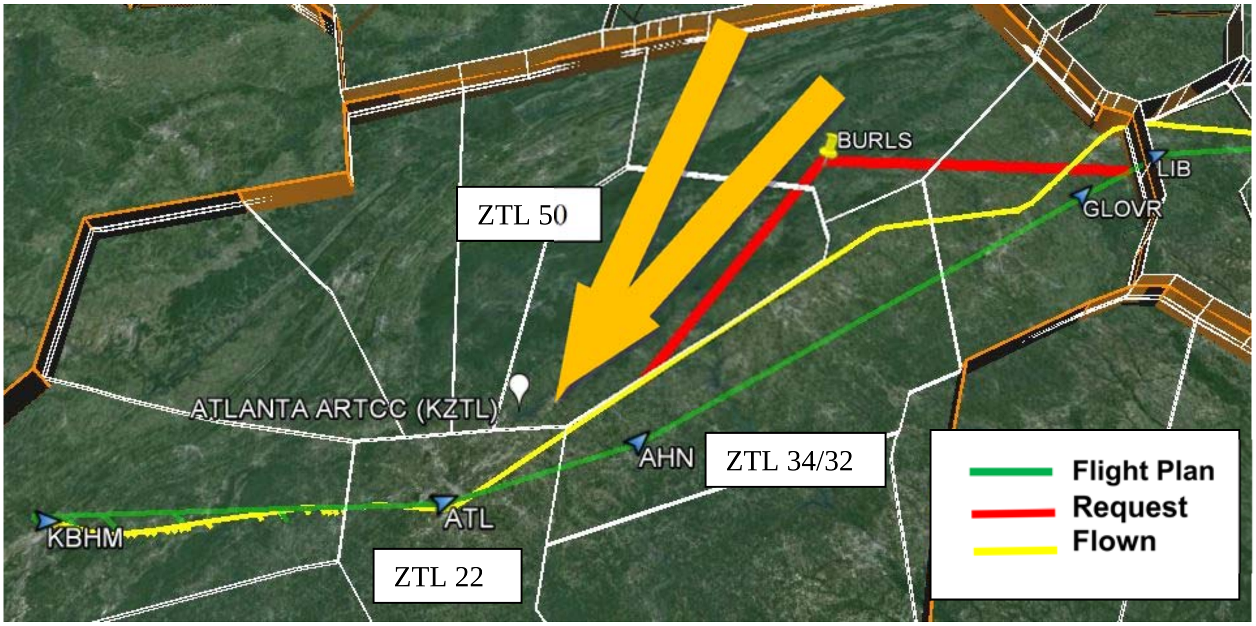


Figure 38 Scenario 116 – request flies opposite major flow (Map obtained from Google Earth).

4 Summary and Insights

All of the controllers interviewed showed an enthusiastic reaction to the possibility of pilots being aware of the sector boundaries and accounting for them in making their requests. The following is a summary of the corresponding recommendations for TAP trajectory change advisories, based on the analysis of each of the factors in the previous section:

1. **Request interaction with active SUA:** Based on the analysis of the controller answers, it is recommended that trajectory change requests maintain the minimum separation of three nautical miles from an active SUA at all times. It is also recommended that if the pilot is aware of the controller workload level, that the trajectory change request maintains about five nautical miles distance from the active SUA during high workload. It should also be noted that some experienced controllers in ZJX commented that they would negotiate with the military authority to allow a trajectory change request to penetrate into an active SUA if the activity in the SUA was low and if there was an operational need such as in the presence of weather. Therefore, closer distances to an active SUA can be entertained if needed.

2. **Request flying along sector boundaries:** Based on the analysis of the controllers' answers, it is recommended that a trajectory change request avoids a point out situation under high workload situations. This can be achieved by ensuring the required 2.5 nautical miles from the boundary between two sectors.

3. **Request sector intrusion:** Based on the analysis of the controllers' answers, it is recommended that a trajectory change request avoids an intrusion point-out situation under high workload situations. This can be achieved by ensuring the required 2.5 nautical miles from the boundary between two sectors. However, based on the smaller emphasis of the controllers' answers on maintaining distance from sector clipping compared to when flying along sector boundaries, it is

expected to be more acceptable that a trajectory change request does not take into consideration the clipping of a sector if that provides an optimal solution.

4. **Request time before handoff to another sector:** Based on the analysis of the controllers' answers, it is recommended to avoid making a trajectory change request when the aircraft is being handed off to the next sector at least under high workload situations. This can be achieved by including sector boundaries in the computation of the trajectory change request. A request desired time before handoff, ranging between two minutes under low workload to five minutes under high workload, may be added to the threshold of three nautical miles before the sector boundary that is used by the automation to initiate an automated handoff.

5. **Request time after handoff from another sector:** Based on the analysis of the controllers' answers, it is recommended that no delay factor be introduced to making a trajectory change request after handoff to a sector, because the controllers would like to hear the request as early as possible.

6. **Request distance from sector boundary after handoff from another sector:** Based on the analysis of the controllers' answers, it is recommended that a trajectory change request that is made shortly after handoff be designed assuming that it will not be handled until the aircraft crosses the sector boundary into the next sector, at least under high workload situations. This can be achieved by including sector boundaries in the computation of the trajectory change. For example, if the delay in handling the request due to the handoff makes the requested trajectory change suboptimal, alternative trajectory changes may be considered that take the delay into consideration.

7. **Request time before handoff to another center:** Based on the analysis of the controllers' answers, it is recommended to avoid making trajectory change requests when the aircraft is being handed off to the next center at least under high workload situations. This can be achieved by including center boundaries in the computation of the trajectory change. A request desired time before handoff, ranging between two minutes under low workload to five minutes under high workload, may be added to the threshold of three nautical miles before the center boundary that is used by the automation to initiate an automated handoff.

8. **Request with multiple waypoints:** Based on the analysis of the controllers' answers, it is recommended that only two additional waypoints be requested under high workload situations. Under low workload this limitation is not necessary; however, if the waypoints are not familiar the number should also be limited to five or seven.

9. **Request with multiple maneuvers:** Based on the analysis of the controllers' answers, it is recommended that no constraint on combining lateral and vertical maneuvers be added when calculating trajectory change requests. Particular attention may be given to making altitude change requests that change the airspace stratum.

10. **Request with unfamiliar waypoint:** Based on the analysis of the controller answers, it is recommended that no constraint on the waypoints' airspace class be added when calculating trajectory change requests. In addition, if it is possible to distinguish familiar from unfamiliar waypoints, preference may be given to the ones that the controllers are familiar with. On the other hand, no problem is anticipated if the automation finds a benefit of using an unfamiliar waypoint as long as it is in the data base used by the controllers.

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14. ABSTRACT
In support of the Flight Trial (FT-2) of NASA's prototype of the Traffic Aware Strategic Aircrew Requests(TASAR) concept, observations were conducted at the air traffic facilities to identify and assess the main factors that affect the acceptability of pilot requests by air traffic controllers. Two observers shadowed air traffic controllers at the Atlanta (ZTL) and jacksonville (ZJX) air traffic control centers as the test flight pilot made pre-scripted requests to invoke acceptability issues and then they interviewed the observed and other controllers voluntarily. Fifty controllers were interviewed with experience ranging from one to thirtyfive years. All interviewed controllers were enthusiastic about the technology and accounting for sector boundaries in pilot requests, particularly if pilots can be made aware of high workload situations. All interviewed controllers accept more than fifty percent of pilot requests; forty percent of them reject less than ten percent of requests. The most common reason for rejecting requests is conflicting with traffic followed by violating letters of agreement (LOAs) and negatively impacting neighboring sector workload, major arrival and departure flows and flow restrictions. Thirty-six requests were made during the test, eight of which were rejected due to: the aircraft already handed off to another sector, violating LOA, opposing traffic, intruding into an active special use airspace (SUA), intruding into another center, weather, and unfamiliarity with the requested waypoint. Nine requests were accepted with delay mostly because the controller needed to locate unfamiliar waypoints or to coordinate with other controllers.

15. SUBJECT TERMS

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